THE HAWAIIAN PLANTERS' RECORD

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A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

The Short Course for Plantation Men.

The University of Hawaii and this Experiment Station have been asked to conduct another Short Course this year. Plans are now under way with this end in view.

The two weeks course will begin Monday, October 11, and end Saturday, October 23. It will be modelled upon the 1919 session, with such changes and improvements as may be advisable. Essentially the same ground will be covered as at the former session.

The success of last year's short course was due largely to those who attended the course and took such active interest in the work under way. Twenty-eight plantations and two Honolulu agencies had representatives in attendance. The twenty-eight plantations sending representatives were divided among the different islands of the group as follows:

15	plantations	on	Hawaii
4	"	"	Maui
4	"	"	Kauai
5	"	"	Oahu

The course is designed to give those who attend a clearer understanding of many of the questions pertaining to sugar production.

There will be lectures, demonstrations, and discussions. There will be no examinations or quizzes.

Insect pests, sugar cane diseases, fertilizers and fertilization, irrigation, cane varieties, cultivations, and watershed forests, are among the subjects to receive attention.

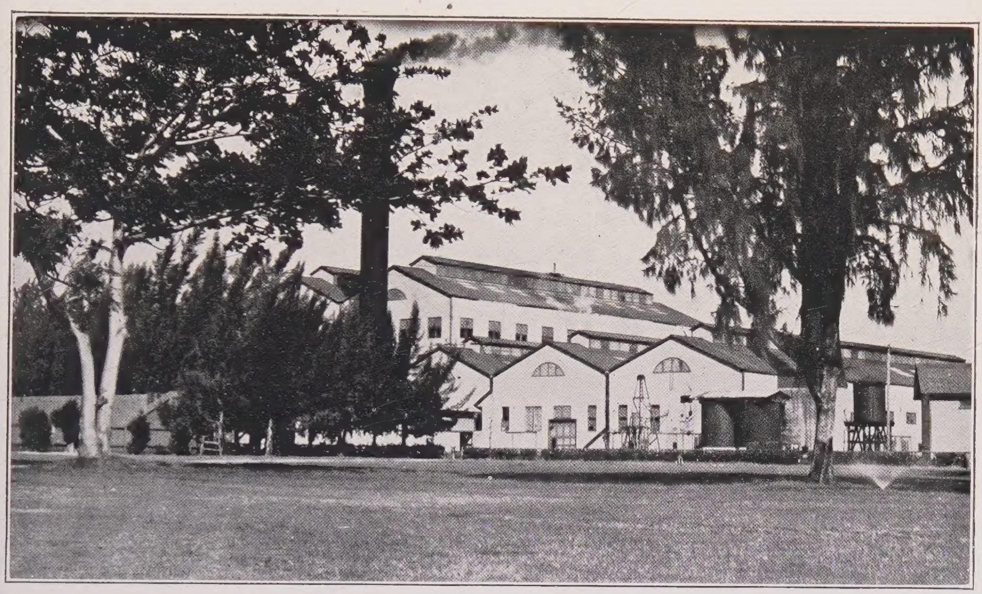
The same liberal support as previously on the part of the plantations in sending their field men to Honolulu for the two weeks course is again needed to make this undertaking the benefit it should be to all concerned.

Trees and Plants as an Aid to Plantation Improvement.

Industrial Service Bureau, H. S. P. A.

Line of laborers' quarters well planned on Maui.

Pleasantly situated Portuguese quarters on a Kauai plantation.



Trees and palms improve the appearance of a mill.

Improvements in mill yards are well worth while.

The Fundamentals of High Mill Extraction.

By A Mill Engineer.

The following paper, under the heading of "A Few Hints to Young Engineers on High Extraction," was originally intended for presentation at the 1918 conference of mill engineers in Honolulu. As there was no conference either in 1918 or 1919, the paper was not published. At the urgent request of a friend the writer now submits this paper for publication. The usual method of treating a paper on milling is to describe the machinery in use, and the advantage or disadvantage of each and every process the cane is subjected to, from carrier to fire room.

The writer is particularly anxious to avoid boosting any one make of machinery, and equally so of knocking any other make. It is his desire to treat the subject from an entirely unbiased viewpoint, with the intention that the following remarks may be applicable to any mill in the Hawaiian Islands, irrespective of the quality or make of machinery in use.

The preparatory machinery, that is the machinery used for preparing the cane for the first mill, should by rights have first call on our attention, but, for the reasons given above, the writer does not intend to go into detail in this branch of the subject.

As a matter of fact, the importance of preparatory machinery has been greatly overrated of late years, and consequently this branch of milling has received more attention than it merits. The writer, however, will commit himself so far as to say that it is very important that the cane be well prepared on entering the first mill. The better it is prepared, the easier it will be to obtain good results in the process of crushing.

Hydraulic Pressure.

As the fundamental principle of milling is the extraction of the juice from the cane by means of pressure, it is the opinion of the writer that the point of primary importance in high class mill work is the proper and effective application of that pressure.

Theoretically there is no limit as to the amount of weight that should be carried on a mill, but in practice the operator has to be governed by local conditions and the strength or quality of the equipment at his disposal. Poor equipment or unfavorable local conditions should not be made the excuse for poor mill work, however. It is the duty of the engineer to overcome adverse conditions and to strive for the best results with the machinery at his disposal.

Only good judgment, tempered by experience on the part of the engineer in charge, can determine the correct amount of weight to carry on a mill. It should be his aim, as high pressure is essential to high extraction, to carry the highest safe working load possible. Roughly speaking, from 70 to 80 tons per lineal foot of roller may be considered good practice.

The writer believes that a word of warning against excessive loading will

not be out of place here. The tendency of operators of late years has been to ignore the factor of safety altogether, load up the mills until something breaks, have the broken part replaced by a stronger part, and so go ahead again. This method of working may be conducive to high extraction, but it certainly is not good engineering practice.

In some factories the engine capacity, or rather the lack of sufficient engine capacity, is the determining factor as to the amount of weight to be carried on the mills. The rectification of conditions of this kind is specifically an engineering problem, and although very interesting, it cannot be gone into in this paper.

It is of the utmost importance in good mill work that the total weight, i. e., the weight applied by the hydraulic jacks plus the weight of the top roller, be utilized to the best advantage. As much as possible of this weight should take effect on the blanket of bagasse passing through the mill. Any weight taken up by the driving pinions, top roller brasses, or the returner bar, is so much waste, so far as useful work is concerned, and should be eliminated as far as possible.

Size and Position of Hydraulic Jacks.

With regard to unequal pressures on different mills, the safe working load for one mill is equally the safe working load for another mill of the same size and make. The only instance where it may be necessary to carry unequal loads is in the event of insufficient engine capacity, and then only when the preparatory machinery is not doing good enough work; then it may possibly be advantageous to reduce the weight on the second and third mills to enable the full pressure to be carried on the first mill.

A top roller is always inclined to ride on the pinion end, due to the action of the driving pinions, and in a mill where the jacks are the same size on both ends of the roller, a higher moisture on the pinion end will be the result. To eliminate this a larger jack should be installed on the pinion end. The operator should remember, however, that this larger jack is provided as a precaution and is no prevention in the event of badly fitting pinions. The mere fact that it is necessary should be sufficient proof that the driving pinions must at all times be kept in good order. The pinions should be of correct size, properly meshed, and always well lubricated. It is very important that the top roller brasses be in good order; neglect or carelessness in fitting may mean a great decrease in efficiency. Some means of offsetting the hydraulic jacks should be provided. This offset is necessary to prevent the brasses from tilting up on the feed side and becoming wedged in the housing. The amount of offset necessary to keep the brasses fairly level will vary in different mills, but as a general rule it will be found that about one inch offset in the first mill, gradually decreasing to about five-eighths inch in the last mill, will be sufficient.

Effective Use of Hydraulic Pressure.

The brasses should be an easy working fit in the housing, and the faces in contact with the housing should be generously supplied with oil grooves and kept well lubricated.

A few years ago it was a common practice to fit shims below the top brasses, with the idea of releasing the pressure on the top roller when the mill was running idle. Just why this was deemed necessary the writer is unable to say. The result in the majority of cases was that when the mill received the feed the top brass would lift on the feed side only, and a great deal of pressure supposed to be taking effect on the top roller was in reality being applied through the shims to the mill cheek. This possibility should be entirely done away with; the top roller brasses with full pressure applied should be at least one-quarter inch clear of the mill cheek on both feed and bagasse sides. By adopting this method the full pressure is bearing on the top roller at all times, and it is only necessary for the roller to lift the merest fraction to assure the full pressure being transferred to the blanket of bagasse passing through. Setting the returner bar too high is another cause for the loss in pressure applied, sometimes overlooked by operators. The proper method of setting returner bars will be gone into a little later in this paper; it is sufficient for the present to remind operators that the returner bar is designed purely for carrying the blanket from the feed to the bagasse rollers. It cannot under any circumstances extract juice, therefore, any undue strain applied to it is so much waste.

Another source of loss is in the driving coupling on the top roller. But if the operator has assured himself that the mill is properly lined up and that the coupling is of sufficient size, he has done all that is possible in eliminating this loss. Although pressure is such an important factor in obtaining high class mill work, it should be understood that all other conditions must be favorable before high pressure can be profitably applied. It is quite possibie to overload a mill under adverse conditions with a pressure of only 50 tons per lineal foot. This does not necessarily mean that the mill is working under a weight that cannot be safely carried by the rollers.

Slippage.

The term "overloading," as used in connection with milling, simply means that the blanket of bagasse passing through the mill is for some reason incapable of lifting and keeping in suspense the top roller. Choking, that is refusing the feed, is always the result of overloading, and this is caused not by the feed and top rollers, but by a slipping of the bagasse and top rollers. Again I want to emphasize that, if high extraction is desired, the remedy is not in reducing the weight, but in rectifying deficiencies in the equipment. To get the best results it is necessary that the blanket should enter the feed of uniform thickness, continue over the returner bar, and pass out at the discharge at the same speed as the surface of the top roller. In other words, there should be no tendency of the top roller to slip past the blanket. Slip always means that the blanket is being broken, and pockets of juice are formed and carried through with the bagasse, which, it can be readily understood, is fatal to high extraction.

As the prevention of any tendency to slip is of so much importance, it is always advisable to surface groove the rollers. The surface grooves should not be any larger than is necessary for the purpose for which they are provided, five to eight grooves per inch being considered good practice. When a very

large tonnage ratio is desired it is sometimes necessary to have large or coarse grooving all through the train of mills; but it must be understood, eliminating the question of higher tonnage, that increasing the size of the surface grooves increases the drainage resistance, thereby decreasing the possibility of the juice being extracted.

Juice Grooves.

It is the fact of cutting down the drainage resistance that makes the juice grooves of so much value. Juice grooves do not extract juice, they merely facilitate in the escape of juice that has already been extracted.

There is great difference of opinion as to the proper width, depth and pitch of juice grooves. The writer does not see why there should be much room for argument on this subject. It is obvious that the width should be as small as possible, the depth large enough to take care of all the juice, and they should be spaced as closely as mechanical reasons will permit. Grooves one-eighth inch wide by one and one-quarter inches or one and one-half inches deep, not more than two inches apart, are what the writer would recommend. It is absolutely essential that these juice grooves be kept clean; if one set of scrapers is not sufficient to do this, two sets should be provided.

Returner Bar Setting.

The setting of the returner bar has a great influence on the correct feeding of a mill. A returner bar set too high causes slipping and choking between the feed and top rollers, as well as unnecessary friction and waste of pressure on the bar itself. The general tendency, however, is to set the bar too low. Although the friction may be reduced by low settings and the mill may run more quietly, that is with less groan, this does not mean that it is doing better work; in all probability it is not doing such good work. The writer rather likes to hear a mill groan a little; it is an indication that it is "on the job."

It is the opinion of some operators that the top roller is responsible for carrying or dragging the blanket over the bar. This is an entirely mistaken idea, although a well roughed top roller does assist to some little extent. The pushing force of the blanket leaving the feed is the principal factor, however.

If the bar is set too low, that is if the space between the top roller and the bar is too large, the blanket passing through will pile up against the discharge roller until the space is packed full before the discharge roller will start to feed. This simply means that the blanket passing over the bar is thicker than the blanket being discharged from the mill; therefore it must be moving slower than the surface of the top roller. In other words, the top roller is slipping over the blanket on the returner bar. Now, as the blanket being pressed against the bagasse roller is thicker than the blanket leaving the mill, the bagasse roller has also to slip past so much of this blanket to assure a uniform feed in the discharge rollers. Unfortunately, however, for this style of setting, the bagasse roller does not always slip just the required amount. As a matter of fact, the discharge rollers generally take a large and small bite alternately, and in this way have a tendency to break up the blanket and leave pockets of juice. A mill

under these conditions is often incorrectly assumed to be doing fine work, because the accumulator weights keep jumping up and down all the time. A returner bar set with too large an increase of opening from toe to heel, i. e., with too low a heel, has exactly the same effect on the discharge rollers.

When a bar is set properly the blanket should travel over it at the same speed as the surface of the top roller and should enter the discharge without any tendency to pile up against the bagasse roller. For the proper setting of a returner bar the operator has to be governed by the speed of the mill, the tons of cane ground per hour, and the per cent fiber in the cane. In theory the bar should be set concentric with the top roller, but this method, owing to the enormous friction, is not practical. The correct method is to allow a slightly increased opening from toe to heel. This increase or clearance should not be more than one-half inch. To insure the correct amount of clearance at all times, it is necessary that the bar toe and holder move forward bodily and in accordance with the amount of wear of the toe on the feedroller. As this is not practical in the common style of returner bar, a good method is to move the bottom of the bar holder forward by means of the adjusting screws at the end of each week's run a sufficient amount to correspond to the wear on the toe of the bar for that week — say one-eighth inch when the bar is new to one-sixteenth inch or one-thirty-second inch after the mill has been running a few weeks and the toe has a fairly large wearing surface.

It is well to remember that a bar set concentric with the top roller does not wear so quickly on the toe as does a bar set with an increased opening from toe to heel. The greater friction of the bagasse passing over the concentric set bar serves to pull it away from the feed roller, but again the greater the friction, correspondingly greater will be the strain on the returner bar bolts and the more difficulty there will be in keeping the feed roller clean.

To curtail this friction and consequently help the working of the mill, the bar should be no wider than is absolutely necessary, which simply means that the centers of the bottom rollers should be as close together as it is possible to get them.

The distance from the heel of the bar to the bagasse roller should not be too great — one-quarter inch is quite sufficient if the bar is set properly. The following rule to determine the height of a returner bar, although not absolutely correct, may be applied with good results in the majority of cases. The distance from the surface of the top roller to the center of the bar in inches to be 1.5 times the tons of fiber ground per lineal foot of roller per hour.

Grouping Rollers of Different Size.

As the prevention of slip is of so much importance, the rollers should be as near the same size as possible, and the operator should try to have all the shells made of the same material. Soft, coarse-grained cast iron is the best material. Hard cast iron, semi-steel, or steel roller shells should not be used if high extraction is desired. The surface of the rollers should be strictly watched during operation and upon the first indication of any tendency to glaze up, or of any smooth patches developing, the affected part should be roughened up by

means of a pneumatic chipping hammer or some other convenient tool. This is equally important on all three rollers.

In arranging a train of mills the operator should group his rollers in lots of three according to size. The three largest rollers should be assembled in the slowest running mill, generally the first; the three smallest assembled in the fastest running mill, etc.

As in the majority of factories that have been in operation for a number of years it is practically impossible to have three rollers of the same size in each mill, the writer submits a few suggestions as to the method of arranging rollers of miscellaneous sizes.

The worst possible combination, in the writer's opinion, is a large top roller with correspondingly small feed and discharge rollers. To explain fully just why this should be so it will be necessary to theorize a little. The duty of a mill, where the cane is thoroughly prepared and properly macerated, is to pass a certain amount of this prepared cane through per hour and to extract as much juice as possible in the process. In other words, to reduce the moisture content of the bagasse leaving the mill to the lowest possible percentage. Any factor that has a tendency to increase the moisture is detrimental. Now, to take an extreme case, say we have a top roller 32½ inches diameter assembled with feed and bagasse rollers of 30½ inches diameter. The blanket will enter the mill and pass over the returner bar at the same speed as the surface of the smaller feed roller, the 30½-inch roller. The blanket should pass out of the mill at the same speed as the surface of the smaller of the two discharge rollers, the 30½ inches diameter bagasse roller. If this theory is correct, the 32½ inches diameter top roller, in the example under consideration, will have to slip 6¼ inches in each revolution. This slip takes effect on a surface of blanket of fully the width of the returner bar. It is obvious that this amount of slip going on day after day is going to wear down the top roller very quickly, but this condition is also very undesirable on account of the enormous waste of power expended in this slip. When the top roller is smaller than the feed and bagasse rollers, the blanket enters the mill and passes over the bar at the same speed as the surface of the smaller top roller, and any slip is taken up by the feed and bagasse rollers and takes effect on a comparatively small surface, eliminating to a large extent the wear of the rollers and the waste of power expended in overcoming friction of the slip. As previously stated, the blanket passes through the discharge rollers at the same speed as the surface of the smaller roller, but the writer believes this condition only holds good up to the point of contact. Immediately after passing the center or point of highest pressure, the blanket is inclined to take the fastest speed of exit, that is, the surface speed of the larger roller. Now as the bagasse in contact with the smaller roller cannot travel faster than the surface of that roller, the quicker release of the blanket in contact with the larger roller causes a series of small ruptures on that surface. If these ruptures appear, as the writer believes they do, immediately after the point of contact has been passed, it is not too much to infer that some of the juice being extracted and taking the path of least resistance to escape from the enormous pressure, will find its way into the ruptures. Where the top roller is the larger the juice in the ruptures is carried out with the blanket of bagasse until the pressure is sufficiently relieved, when

the juice is reabsorbed by the bagasse. But supposing the bagasse roller is the larger, the ruptures will take place on the bottom of the blanket, and the juice being carried out will escape through the juice grooves in the bagasse roller while still under pressure and before the bagasse has had a chance to reabsorb it. The same theory may be applied to the feed and top rollers, with this difference, however, that pressure on the blanket leaving the feed rollers is never entirely released, as the resistance of forcing the blanket over the returner bar has to be overcome.

It is the writer's opinion, founded on personal experience, that the best results (that is the lowest moisture) can be obtained in a last mill by having the bagasse roller slightly larger than the top roller. In summing up the above remarks on the different methods of arranging the rollers of miscellaneous sizes, it will be seen that it is very bad practice to assemble a large top roller with a small bagasse roller. The bagasse roller can be quite a bit larger than the top roller, however, before the detrimental effect is noticeable. The feed roller can be slightly smaller and quite a bit larger without materially affecting the extraction.

In the assembled mill, with rollers of equal or different sizes, the importance of close setting cannot be too strongly emphasized. It is worse than useless to pile weights on the accumulator, if the rollers are not set close enough to insure the weight being transferred to the blanket of bagasse. Some operators believe in setting a mill to take a certain fixed tonnage per hour, and keep running up to the full tonnage and at a uniform speed at all times. This method has much to recommend it, but unfortunately cannot always be carried out. Many factories on these Islands have to keep changing speed at any and all times to accommodate the irregularities in cane transportation. Then, again, it is not always possible to run with a blanket of the desired thickness. From unavoidable reasons irregularity in feeding will frequently occur in the very best conducted factories. To take care of these irregularities it is necessary that the mills be set as close as it is possible to get them. This is especially important in the last mill of a train; in fact the necessity of close setting increases in each mill, from first to last, and this importance is greatly magnified where the gear ratio is such that the speed of the mills increases from first to last. It is a natural error to assume that by setting the top and bagasse rollers up metal to metal, all that is possible has been done by way of close settings, losing sight of the amount of slack or lost motion that has to be overcome before the full pressure can take effect on the blanket. This lost motion is the result of a combination of small defects, sometimes unavoidable, such as play of the top brasses in the housing, badly fitting top and end caps, too small setting-up screws, slackness in king bolt and end cap bolts, badly fitting journals and spring in the mill cheeks. The inequality of the two upward forces acting upon the top roller tends to emphasize the effect of any small defect in the assembled mill. In other words, the force applied to the top roller by the bagasse roller, being greater than the force applied by the feed roller, the resultant of these two forces acts obliquely on the top roller. This, and the right-handed revolution of the top roller, both tend to lift the top roller in a slanting direction across the perpendicular, downward force applied by the hydraulics. It is the effect of this oblique force, acting on the mill cheek

instead of acting against the downward force, that is responsible for most of the lost motion.

Lining Up the Rollers.

In setting a mill the operator should always bear in mind the great importance of having the rollers parallel; carelessness in this way means a great deal of unnecessary friction through end thrust of the rollers on the journals and brasses, and may even be the cause of forcing a roller shell off the shaft.

Setting the Rollers.

The writer recommends the following method in setting a bagasse roller. With the full hydraulic pressure applied set the bagasse roller up metal to metal with the top roller, making sure that the two ends of the roller are bearing equally. Next, with the mill turning over slowly, release the hydraulic pressure, make a mark on the setting up screw on the pinion end and tighten this end up as far as it will go. By observing the position of the mark on the setting up screw on the pinion end, the other end can be tightened up exactly the same amount. It is important that the pinion end be set up first, because if the other end is tightened up first it will be found impossible to get the pinion end up the same amount. This should be gone through every day for three or four days at the beginning of the season; then afterwards, when everything is thoroughly worked into position, once every week will be enough.

No definite rule can be laid down for setting a feed roller; the operator has to set the roller just to take the desired feed, always bearing in mind that the feed opening should be as small as possible and that the roller should always be parallel with the top roller. It is a good plan to keep setting the feed roller up a little every two or three weeks, as there is a great deal of wear to be overcome; besides it will generally be found that the longer a mill has been in operation the smaller the feed opening required. Some operators maintain that closing up the feed opening too much is likely to raise the moisture content of the bagasse, but this is only possible when a mill is running very fast or with a very thin blanket, and then only when the bagasse roller is not set up properly.

Maceration.

The question of macerating may be said to work second in importance to that of application of pressure, and in a factory where the amount of macerating water applied is limited to a certain insufficient quantity it is extremely important that every drop be utilized to the best advantage. The practice usually followed in these Islands in a twelve-roller mill is to apply all the water immediately behind the third mill. The very dilute juice extracted by the fourth mill is collected in a tank and by means of a pump applied as maceration behind the second mill. The juice extracted by the third mill is also collected and pumped up behind the first mill. In some factories the juice from the second mill is applied as maceration in front of the first mill, but unless the preparatory machinery is doing exceedingly good work this last application is of very little value.

In fifteen-roller mills and nine-roller mills the same method is followed; the juice will be returned one time more in the fifteen-roller, and of course there will be one less application in the nine-roller than in the twelve-roller.

Some operators use the dilute juice from the feed rollers only for macerating in the preceding mills, and although this is a much more elaborate method, it nevertheless has much to recommend it.

Just as the engineer, who, owing to obsolete and inferior mill machinery, is handicapped and has to "carry on" at a great disadvantage, so it is in the case of inadequate boiling house equipment. Lack of capacity in heating, evaporating or boiling equipment and uneconomical handling of same, by cutting down the maceration, greatly increases the difficulty of obtaining good mill work. It is comparatively easy to apply maceration effectively where 40 to 50 per cent is carried, but where only a small amount can be carried great care has to be exercised in the application to obtain good results. The writer does not feel qualified to say what the right amount should be; it will vary with different varieties of cane and different fiber in cane. He does feel safe in saying, however, that any amount below 40 per cent is not enough.

It is very important that the maceration be distributed uniformly throughout the blanket of bagasse and that it be applied as soon as the blanket is released from the mill. In other words, it should be applied before the blanket has had time to absorb any air. For this reason it is almost essential that macerating scrapers be used, as they are designed specifically for this purpose, and although they are by no means perfect in design, nevertheless by a little judgment in manipulating them, an almost perfect maceration can be obtained. Operators should remember that it is just as important to have a perfect maceration in the first mill as in the last. The maceration water should be applied at as high a temperature as it is possible to get it—200° F. is not any too high. It is universally agreed that hot water will penetrate further into the fine particles of bagasse and absorb more sucrose than will cold water. Besides, hot water applied in front of the last mill and mixing with the extracted juice helps to keep the juice sweet and free from inversion in the process of multiple maceration. Then it is just possible that the hot water if not used as maceration would be going to waste, therefore adding it to and slightly raising the temperature of the mixed juice amounts to a slight saving of steam in the heaters.

It is absolutely essential that one man on each shift, and one man only, be instructed to look after the maceration. If every Tom, Dick and Harry be allowed to interfere with the macerating value, the results obtained may possibly be interesting, but they certainly will not be uniform. The engine tender is possibly the best man to put in charge, as he is usually fairly intelligent, has lots of time, and, knowing the speed of his engines, can with a little practice estimate fairly accurately the quantity of cane going through the mills at any and all times. He should be instructed to take samples of the crusher or first mill juice and also the mixed juice at least every hour, taught how to take the Brix of each juice and how to work out the maceration, and instructed to enter the results in a book for the day's run. He should also be instructed to use his judgment between sampling times as to the approximately correct amount of maceration to apply, if for some reason the mill has to be run slower. It should also be a

hard and fast rule that in the event of the mill being stopped the maceration be immediately shut off. Once the tender has been properly instructed it will be found that he will take pride in being accurate, and it is astonishing how uniform he will be able to keep the maceration.

In factories where the amount of maceration is limited and it is found necessary to use the very dilute sweetening off water from the mud presses as maceration in front of the last mill, it will be essential to have a boy told off to sample this sweet water also. Samples should be taken at least every half hour, and in the event of the Brix running above a specified amount, the cause should be investigated. Although it is not a correct indication of the amount of sucrose, it is a safe rule not to allow any maceration applied in front of the last mill with a Brix of over 1.5%, as it will be sure to affect the results.

Controlling the Mill Work by Mill Extraction Tests.

To insure uniform and consistently good work being done throughout the season, it is essential that the operator have the cooperation of the chemist in taking samples periodically from all the mills, thereby keeping himself posted as to what each mill is doing and enabling him to have them tuned up to the highest pitch all the time. In taking samples of individual mills, since it is comparative results that are desired, it is not really important whether those samples be "dry crushing" or otherwise. The writer, however, is not at all partial to dry crushing as a means of ascertaining the work done by individual mills. Dry crushing tests are taken under extraordinary circumstances and at the best are only an indication of pressure. In fact the results obtained should be directly proportional to the pressure applied. Dry crushing does not give any indication of the efficiency of maceration or of the correct drainage of the extracted juice. Then, again, it gives no indication as to whether the mill is properly set or otherwise, as the feeding conditions under dry crushing are entirely different than when the mill is running under normal conditions. And lastly, in taking dry crushing tests from all the mills, if it is done properly it is necessary to shut off the maceration entirely, stop the cush-cush conveyor and to allow the cane to work all the way through the train of mills. To avoid making any break in the blanket, the last mill has to be taken first. This, as can easily be seen, is a long and laborious job, besides being very hard on the mills.

The writer believes that the correct way to sample individual mills is just to take them as they run under normal conditions. In other words, find what moisture, sucrose in bagasse and extraction you are getting from twelve, nine, six and three-roller mills, respectively. The moisture is the best indication of what a mill is doing; if the moisture as indicated by the last test shows any perceptible increase over previous tests it is a sure indication that the mill requires tuning up. These tests should be taken at least twice each week, and a complete record kept for comparison from week to week and from year to year.

Large Grooving for First Mill.

In a mill where the preparatory machinery is insufficient, or in other words, where the cane entering the second mill is not sufficiently prepared to assure the

maceration being effective, it is advisable to try large grooving in the first mill. This large grooving, if the grooves in the top roller are meshed with the grooves on the bottom rollers, tends to cut up the cane, and although the extraction in the first mill may be decreased, nevertheless by the cane being better prepared to receive the maceration it really amounts to an increase in the other mills. This is the only instance where large surface grooving may be said to have preference over small surface grooving in regard to extraction.

Speed Ratios of Rollers.

It is generally agreed that the present speed ratio of mills on these Islands, where the speed increases from first to last, is out of date and undesirable in the present advanced stage of milling. It is popularly supposed that it would be more correct to have the mills all running at the same speed.

Where the question of obtaining extraction alone is considered, the correct method undoubtedly would be independent drive for each mill, and this, in the writer's opinion, is the strongest argument that can be advanced in favor of electrification of mills.

There is still some difference of opinion amongst engineers with regard to the speed at which mills should be run to do the best work. Some maintain that high surface speed of rollers with thin blanket is the correct method, while others agree with the writer, that, providing the juice drainage is sufficient, just as good results can be obtained at the same tonnage ratio with low surface speed and correspondingly thicker blanket.

In conclusion the writer, with apologies if guilty of sounding a note of discord, feels it his duty to request mill operators, especially the young, ambitious operators, not to forget that they are first of all engineers. In these days of so-called efficiency and craze for high extraction, it is only too easy to forget this very important fact.

Variety Test in Kohala.

In a small variety test comparing Yellow Caledonia, Badila and H 146, in adjoining water course, recently harvested at Union Mill Company, Kohala, the following results were obtained:

Variety	Area	Tons Cane per Acre	Q. R.	Tons Sugar per Acre
Yellow Caledonia	.185 a.	39.2	7.15	5.48
Badila	.223	35.8	6.11	5.86
H 146	.364	28.4	6.15	4.61

Land Titles and Surveys in Hawaii.*

By Arthur C. Alexander.[1]

Introductory Note.

The following article was written for presentation to a small gathering of well-informed men and the subject is not treated in as extended or as complete a manner as would have been the case if it had been written for publication. Anyone wishing to go further into the subject is recommended to read a "Brief History of Land Titles in the Hawaiian Kingdom," by W. D. Alexander, published as an appendix to the Surveyor General's Report in 1882 and reprinted in Thrum's Annual for 1891; and also a series of articles on "Land Matters in Hawaii," by C. J. Lyons, published in the "Islander" in 1875 and reprinted in the Report of the Surveyor of the Territory of Hawaii for 1902. The various Acts of the Legislature under which the Land Commission was organized and operated may be found in the Appendix to the Revised Laws of Hawaii, 1905.

For the benefit of other surveyors a list of those who did surveying for the Land Commission is appended (Appendix A) to this article with brief comments on the quality of their work and their individual peculiarities. In preparing this list the writer has drawn freely on the experience of others as well as his own, and wishes here to express his indebtedness to those who have helped him with their comments. There is also appended (Appendix B) a discussion of the rate of change in the magnetic declination in Hawaii.

Hawaiian Land Subdivisions.

Some knowledge of the ancient system of land subdivision in Hawaii is necessary in order to understand the peculiar situation that has developed from it.

The largest subdivision of land was the "moku," or district. Each of the four largest islands was divided into several such districts, the names in many cases being repeated, as the windward districts of Koolau and Hamakua and the leeward district of Kona, which appear on at least three islands. The moku seems to have been a geographical subdivision only. There were no lords or administrators over these districts, as districts.

Each moku in turn was divided for land holding purposes into a series of lands called "ahupuaas," varying greatly in size and shape. Theoretically each ahupuaa contained a "kai" (sea fishery), a stretch of "kula" (upland), and some "kuahiwi" (forest and mountain land), so that it could furnish everything that might be needed by the holding chief and his retainers for their support. As a rule, the ahupuaas consisted of strips running from the sea up the mountain side and were usually bounded by natural features, such as gulches, ridges and streams. In many instances the ahupuaa, instead of being a continuous strip, consisted of a number of detached pieces called "leles." This was particularly

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the case where a large number of lands were crowded into a comparatively small area, as in the vicinity of the larger towns.

The ahupuaas were subdivided into smaller lands, called "ilis," the arable portions of which in turn were divided into small tracts, called "moos," or "mooainas." These last subdivisions were for purposes of cultivation only. The names of the mooainas were in reality field names. The ilis varied even more than the ahupuaas in size and form, leles being the rule rather than the exception. A distinct type among the ilis was the "ili kupono," or simply "ili ku," which was an independent subdivision for land holding within the ahupuaa. In some cases, as in the ahupuaa of Hanapepe on Kauai, where the big independent ilis of Eleele, Kuiloa, Koula, Manuahi, etc., took up practically all the land that was of value, the ili kuponos are of more importance than the ahupuaa itself.

The original subdivisions were made some time in the far distant and obscure past and have been rigidly adhered to ever since. It was the business of the inhabitants of any land to know its boundaries definitely, so that they could keep off trespassers and not trespass themselves on adjoining land. This knowledge was imparted by taking them at stated intervals on a pilgrimage around the land. The elaborate subdivision of the land is evidence of the teeming population that once existed here, which is corroborated by the testimony of early visitors and the evidences of cultivation that we find everywhere. In ancient Hawaii there was no unoccupied land. It was all "taken up."

Ancient System of Land Tenure.

Originally the ultimate title to all land was vested in the reigning chief. No one could hold or occupy land without his consent. The communal, or tribal, system of land tenure existing in other parts of Polynesia did not exist here. The lands were parcelled out among the principal retainers of the king on his accession and their tenure was not usually disturbed so long as they rendered the service and tribute exacted by their sovereign. To have disturbed them might have fomented dissatisfaction and revolt,—a condition to be avoided. The number of lands granted any chief varied with his rank and influence. Under the chiefs the arable land was parcelled out again among the common people living on the land, who in turn rendered various services to their landlord and cultivated certain pieces of land called "koeles" for him. In later years the tenants worked on the koeles once a week, on Friday, and these came to be called "poalimas," poalima being the Hawaiian word for Friday. The tenants as a rule did not migrate and lived on the same lands for generations. The fact that the landlord was dependent on them for service both in peace and war tended to render their tenure more stable. As may be seen it was strictly a feudal system, with this distinction, that the tenure of land was entirely dependent on the life of the sovereign or his ability to maintain the throne.

The name "konohiki," meaning originally the landlord's agent in charge of the land, came in time to be applied to the land under his care, "konohiki land" meaning land held by a chief, i. e. an ahupuaa or ili; and the name "kuleana," meaning originally "rights," came to be applied to the land held by the tenant.

I shall use both terms in this way throughout this paper without further explanation.

Land Commission and "Mahele" of 1848.

Prior to the establishment of the Land Commission, transfers of land, in order to be valid, required the approval of the king and premier. There was no such thing as a fee simple title. With the advent of foreigners and foreign business methods, it soon became apparent that a radical change would have to be made in the system of land tenure. Fortunately the king, Kamehameha III, and the leading chiefs were thoroughly alive to the situation. In 1846 there was formed a "Board of Commissioners to Quiet Land Titles," commonly known as the Land Commission. This commission as first organized consisted of two white men, two full-blooded Hawaiians and one half-white. John Ricord, the attorney general, was chairman of the board. It organized and began its labors on February 11, 1846, and it was not dissolved until March 31, 1855, nine years later. It sat as a court of record, with power to confirm or reject all claims to land arising prior to December 10, 1845. All claimants to land were required to file their claims before the Land Commission for confirmation before February 14, 1848, or be forever barred.

I have not time to go into the details of the great "mahele," or division, of the lands that took place in 1848. The king, to his everlasting honor, voluntarily gave up all his rights in the land, which was divided ultimately into three portions,—one to the chiefs, one for the support of the government, and the third for the sovereign's personal use. These we know by the names of Konohiki, Government, and Crown Lands.[1] A one-third interest in the konohiki lands was retained by the government, and in order to get an allodial title in fee simple the payment of "commutation" to the government was required, either in land or in cash equal to one-third of the unimproved value of the land at the time of the mahele. Out of the konohiki lands were taken the holdings of the tenants, the "kuleanas." Thus the chiefs had to give up one-third of their lands to the government and a theoretical one-third to their tenants. It was only after a long and earnest discussion in the Privy Council that they consented to do this. It was a great sacrifice on their part for the common good, but at the same time they obtained fee simple titles that could not be disturbed, except by due process of law. The kuleanas, as finally decided, were exempt from commutation, except in the towns of Honolulu, Hilo and Lahaina. This was on the theory that in the country districts the government commutation having already been paid by the konohiki, the kuleanas ought to be exempt,

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[1] This division is recorded in the so-called "Mahele Book." In this book the lands held by each chief are entered in two lists on opposite pages. The king signed one list quit-claiming those lands to the chief and the chief signed the other list quit-claiming the remaining lands to the king. After this subdivision was made, the king made a second subdivision of the lands given up by the chiefs, setting aside the main portion for the support of the government and retaining the rest for his own use. This second subdivision was inserted in the "Mahele Book" after the first, the two resultant lists being both signed by the king.

while the town lots, not having been taken out of konohiki land, ought to pay commutation.

The Land Commission worked with great energy and singleness of purpose and accomplished a most difficult and arduous task. They made many mistakes, but when one considers that nearly 12,000 individual claims were adjudicated by the commission, involving visits to all the principal islands and the hearing of a mass of testimony, it is surprising that more mistakes were not made. The work required haste in order to insure its completion, as there were many exigencies that might have stopped and undone all that had been accomplished, as, for instance, the death of a progressive ruler in entire sympathy with the work of the commission and the succession of one less liberal and helpful. The sins of the Land Commission were sins of omission rather than of commission, and are being gradually corrected as they come to light. Whatever injustices were committed were unavoidable under the circumstances.

Boundary Commissioners.

It was manifestly impossible, with the limited time available and the scarcity of surveyors, to survey all the konohiki lands, and in 1852 the Land Commission was empowered by Act of the Legislature to grant awards on konohiki lands by name only and without survey. Some ten years later, by another Act of the Legislature, Boundary Commissioners were created, to whom the owner of any konohiki land might apply for the settlement of its boundaries.[2] It is nearly fifty-eight years since the first Boundary Commissioners were appointed, and yet there are a surprisingly large number of lands whose boundaries have never been surveyed or settled. In the district of Lahaina, for instance, there are over twenty such lands. The difficulties in the way of determining the boundaries of these lands have been increased immeasurably by the death of all the old "kamaainas" who were familiar with these boundaries. In order to close up the work of the Boundary Commissioners the last Legislature passed an act requiring the surveying and settling of all such boundaries within four years from July 1, 1919, and it is to be hoped that this will be accomplished.

Awards, Patents and Deeds.

Many of the owners of konohiki lands assigned to them in the mahele failed to apply for Land Commission Awards within the allotted time. For the relief of these, an act was passed in 1860 empowering the Minister of the Interior

[2] At first there was a Boundary Commission, consisting of two members, appointed for each judicial circuit; then the plan of a single Commissioner for the whole group was tried, and finally, in 1868, the present arrangement of a single Boundary Commissioner for each judicial circuit was adopted.

to grant awards on these lands if applied for before the last day of June, 1862. Sixty-four awards, known as "Mahele Awards," were issued under this act.[3]

By Act of the Legislature in June, 1848, certain government lands in the district of Honolulu were set aside for the support of the garrison at the Fort, known as "Fort Lands." In 1851 these lands were sold at auction, after fifty acres had been reserved for the Royal Hawaiian Agricultural Society. A series of separate awards for these lands was issued by the Land Commission, designated by the letters "F. L." (Fort Lands). This makes three classes of awards,—(1) the Land Commission Award pure and simple, (2) the Land Commission Award F. L., and (3) the Mahele Award.

These awards conveyed a title to the land "less than allodial," under which, by Act of the Legislature in 1854, the owner might bring any action at law as if he "had received a Royal Patent for the same." The holder of an award was entitled to a Royal Patent in confirmation of his title on application to the Minister of the Interior and the payment of the commutation, but, as they could not be dispossessed of the land, quite a large number of owners were content to let things run on as they were without applying for patents. It was only a few years ago that a law was passed providing for the appraisement of the commutation on all lands subject to commutation that had not been patented and the adding of interest to the commutation if not paid before a certain date. This has resulted in patents being issued on most of the unpatented awards.

In addition to the patents issued in confirmation of awards, there are three other classes of patents,—(1) patents issued on government land sales and homestead lots, known as "Grants"; (2) a few patents issued on government lots and remnants in Honolulu, known as "Public Works Grants" and designated by the letters "P. W.," and (3) patents issued in 1883 to the Board of Education on various school and church lots throughout the islands. The government in recent years has also conveyed title by quit-claim and exchange deeds, and the writer knows of at least one so-called "adjustment deed," but in this case the land was also covered by a patent. There are many cases where more than one award or where an award and grant were inadvertently issued on the same land. Examples are also common, particularly in recent times, where one title has been knowingly superimposed upon another. This has happened where the government has acquired land already under patent or award and has reconveyed it in parts, issuing patents for these parts. All this has tended to increase the complexity of our land titles, already complex enough.

The crown lands, until 1865, when an act was passed making them inalienable, were treated by the sovereign as his own private property and freely sold to fill the royal purse, which suffered from chronic depletion. These conveyances of crown lands are known as "Kamehameha III and IV Deeds." They add another element of complexity to our system of original land titles,—a system that has simply grown without plan or forethought.

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3 A second act for the relief of delinquent konohikis was passed by the Legislature in 1892, whereby the Minister of Interior, under certain conditions, was "authorized to issue Royal Patents (Grants) to all konohikis, or to their heirs or assigns, where such konohikis failed to receive awards for their lands from the Land Commission or from the Minister of Interior as provided by the Act of August 24th, 1860." This Act remained in force until June 1, 1895, on which date all unawarded and unassigned lands became finally the property of the government.

Complications of Title.

The Land Court, established in 1903, was expected to simplify matters by uniting in one title adjoining groups of heterogeneous titles. In time it will do so, but up to the present it has tended to complicate rather than simplify.

To show the heterogeneous character of Hawaiian land titles let us take a hypothetical case. Suppose a tract of land comprising originally four separate pieces, consisting of (A) land awarded and patented, (B) land awarded and not patented, (C) land awarded by name and not patented, (D) land registered in the Land Court, is subdivided into lots for sale. The lots are put on the market at prices depending solely on the character of the land and their relative positions and not in any way on the title. The purchasers of lots containing only portions of (A) obtain titles that are complete. The purchaser of a lot containing part of (B), although he pays the same relative price, to perfect his title must have a description prepared of the unpatented portion of his lot, pay commutation on it and pay for a patent. If the lot contains part of (C), after having had a survey made of this part, the purchaser will also have to go before the Boundary Commissioner and get a Boundary Certificate before he can pay the commutation and get a patent. If there is a part of (D) in the lot bought, he must have a plan and description prepared of this part for the Land Court so as to get a Land Court Certificate of Title for it. If he is unfortunate enough to buy portions of two or three of these pieces, he may have to pay for his lot twice over before he can get a clear title. This is an extreme case, but it illustrates well the want of simplicity in our land titles.

Character of Early Surveys.

The greatest defect of our land system, however, has not been its complex character, but has been the imperfect character of the earlier surveys and descriptions. Under the conditions existing at the time of the Land Commission the wonder is that so much good work was done. With ten or twenty thousand surveys to be made at the same time, with no trained surveyors to be had, and with a limited supply of rather inferior instruments, the Land Commission was certainly "up against it." At the same time the members of the Commission were absorbed in the legal phases of their work and did not seem to realize the importance of accurately describing the lands awarded. A remarkably able statement of rules and principles was drawn up for the guidance of the Commission, but the surveyors that they employed had no such statement to guide them. They were not informed as to how they were to do their work, what land was to be included or what excluded, what degree of accuracy was required, or how corners were to be marked. With a few shining exceptions, most of the surveyors had no idea of the value of accuracy, and the instruments used were of all kinds from a ship's compass to an engineer's theodolite. No one was required to show his qualifications before being employed by the Commission as a surveyor, and absolutely no effort was made to test the accuracy of the work done. As a matter of fact, under the circumstances it would have been a physical impossibility to have done so. Only in rare instances were corners marked and

adjoining surveys made to agree. In general each piece of land was surveyed independently, no stakes being placed. Consequently overlaps and laches were the rule rather than the exception. Add to this the erratic behavior of the magnetic needle here and the meager descriptions given, and you have some idea of the difficulties met in relocating the original boundaries of the awards and why a special sort of education is required in order to do land surveying in Hawaii.

In addition to technical training and experience, a good understanding of the Hawaiian language is necessary to the local surveyor, and also some knowledge of the individual peculiarities of the early surveyors and their work. One of these, for instance, used a very defective compass and, while his distances are good, his bearings are utterly unreliable; another had a compass with the line of sight at an angle of a few degrees with its needle, so that his surveys have all to be swung through the same angle to fit the ground; another used a theodolite and measured the angle made by each line with the magnetic bearing of the first course; others, instead of writing out their descriptions in terms of the magnetic bearings at each corner, used the average magnetic north of all the corners, obtained by taking back sights at each corner.[4] These are only samples of the things surveyors here have to learn by experience. The magnetic needle here will often show a variation in direction of over a degree in a distance of a few hundred feet, and different compasses will sometimes show almost as great a variation between their readings.[5] This increases still more the difficulty of retracing the original surveys.

Changes in Magnetic Declination.

Another important item that has to be allowed for in rerunning old magnetic surveys is the progressive change in the direction of the magnetic north. From the time of the Land Commission to date (March, 1920) there has been a total change of approximately 2° 00′. This change has been in a clockwise direction. As a resunlt, 2° 00′ must be added to all northwest and southeast bearings of 1850, or thereabouts, in order to translate them into magnetic bearings of 1920, and similarly the same amount must be subtracted from all northeast and southwest bearings of 1850. The rate of change is subject to a progressive variation, which, though small, is not negligible. This change in the magnetic meridian at the present time is at the rate of nearly 2.25 minutes per annum.[6]

Relocation of Boundaries.

To go on the ground without any previous preparation and attempt to locate the corners of an award would be folly in most cases. The problem is not nearly so simple. First, the original description should be tested for closure. This will help in adjusting the sides if it does not fit the ground. A preliminary survey should then be made of the ground and all landmarks carefully located and

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4 See "Appendix A" to this article for list of early surveyors with comments.

5 The local variations in the magnetic declination are discussed quite fully in "No. 11" of C. J. Lyons' articles in the "Islander," to which anyone interested in the subject is referred.

6 See "Appendix B" to this article for a more detailed statement as to the rate of change in the magnetic declination.

plotted on paper, the magnetic declination being observed. It requires some experience and judgment to determine what landmarks are pertinent. Now with everything on paper in miniature, the surveyor can plot on his plan the original survey and shift and adjust it until he is satisfied that he has the best location. That is not all, however; he should also take into account the adjoining surveys and plot them too on the plan, remembering the rule that the earlier title governs, for, as I have said, adjoining descriptions were not usually made to fit. Having satisfied himself as to where the boundaries lie, it is not a difficult matter to run them out and mark them on the ground. This may seem like a long drawn out process, but it is the only safe and sure way to proceed and is invariably the quickest way to get satisfactory results. It is needless to say that the problem of overlaps and laches is one of the most difficult that the surveyor in Hawaii has to solve. Another difficult problem, which, however, is not peculiar to Hawaii, is that of shifting natural boundaries, as streams and shoreline.

Work of Hawaiian Government Survey.

The awards issued by the Land Commission are recorded in ten huge volumes. There is a statement as to general location, a brief description by metes and bounds of each parcel, usually in Hawaiian, an outline plan showing the adjoining owners and nothing more, sometimes not even as much. Practically no general maps showing the relative positions of these parcels with respect to each other and the surrounding topography were in existence before the establishment of the Hawaiian Government Survey in 1872. The work that was done by this survey in the following years in the way of preparing such maps has been of inestimable value to the public. It is hard enough to locate a kuleana,—say in Waikiki,—with a general map of the district, but think what it would be without such a map! Another great service that the Government Survey has rendered, which the general public cannot appreciate, has been the introduction of a system of surveying by the true meridian instead of the magnetic and the establishment of carefully located and marked points from which the direction of the true meridian can be readily obtained. Still another service rendered by the Government Survey has been the raising of the standards of local surveyors and the improvement in their methods over what they were prior to 1872. It is fortunate for us that this valuable department has been kept almost entirely free from political interference during the many changes in government that have taken place since it was started and has been able to maintain throughout this period the same high standard of work and service.

Improvement in Standards of Surveying.

A feature of land surveying in Hawaii that deserves mention and which people are not generally aware of, is the great improvement during the last twenty years in the quality of the work done by the local surveyors. Twenty years ago a survey closing within one foot in one thousand was considered quite accurate, even in town. What we might call "precise surveying" was not

at all common. Now the situation is reversed and "precise surveying" is the rule instead of the exception.

Several factors have contributed to this result, the most potent of these being the influence of the Land Court. When the title of a piece of land is guaranteed for all time by the government, it is absolutely necessary that it be described in such a manner and with such accuracy that there can never be any question as to the location of its boundaries. Those who were responsible for the drafting of the Land Registration Court Act passed in 1903 and for its early administration appreciated this fact fully and saw that the characer of the surveys filed was properly safeguarded. During the first few years of its existence the Land Court employed technical experts to check the accuracy of these surveys. Recent amendments to the act have placed this work under the Territorial Surveyor and require the testing of all surveys on the ground. Having been connected with the Land Court in an official capacity for several years, the writer has observed with considerable satisfaction the salutory effect its standards have had on the local surveyors.

Another factor in making the local surveyors improve the quality of their work is the act relating to the filing of plans passed in 1905, and amended a few years later so as to require all plans filed with the Registrar of Conveyances to be tested and approved by the Territorial Surveyor before acceptance. It seems almost incredible, but up to the passage of this act land in this city was bought and sold by lot and block number as shown on maps copied in the books of the Registry of Conveyances,—maps which do not give the length and bearing of a single line and which are of such a scale and so imperfectly drawn that it is impossible to even approximate the true dimensions of the lots. Such a law was absolutely necessary for the protection of the public and should have been in force years ago.

A third and more recent step in advance has been the application, where the government is involved, of the same safeguards to the surveys filed with the Commissioners of Boundaries. Maps are also required to be filed with the Commissioners to be kept as permanent records similar to the maps accompanying Land Court Petitions. Anyone who has dug over the records of the Boundary Commissioners, which only contain notes of survey unilluminated by maps, will appreciate this change. The evolution in the methods of these Commissioners is worthy of note from the days when not even notes of survey were required and the boundaries of lands were adjudicated and settled by reference to natural features, to the present time when not only are maps and notes of survey required, but these are also carefully scrutinized for possible errors.

As has been shown, there has been real progress made during the last twenty years towards standardizing our land surveys, if not our land titles, and it is to be hoped that there will be no retrogression in the future.

APPENDIX A.

Surveyors for the Land Commission.

Alexander, W. P.—One of the most careful surveyors of that time.

Bailey, Edward—Work was fairly good; main fault was the correcting of errors of closure in the office without testing on the ground.

Baldwin, Dwight—Surveyed only one or two small pieces in Lahaina.

Bishop, Artemas—Had no conception of the value of accuracy or the desirability of making adjoining surveys agree, consequently his surveys are extremely inaccurate and inconsistent.

Dillon, James—Work was fairly good; used an engineer's theodolite and the magnetic north of the initial point, a method which has the fault that a blunder in reading or recording the magnetic bearing of the first course may swing the whole survey through an angle of several degrees.

Dole, Daniel—Surveyed only a few small kuleanas in Waikiki.

Emerson, John S.—The accuracy of his work was impaired by the employment of an unreliable chainman, who, in staking out land sales, Joseph S. Emerson reports, was in the habit of placing the pin in the ground beyond the end of the chain, thus giving more land than the calculated area called for.

Fuller, John—An extremely careful surveyor; both Joseph S. Emerson and E. D. Baldwin, who have had much experience in rerunning his surveys, say that he was the most accurate surveyor of his time.

Gower, John T.—A very careless surveyor.

Hopu, Asa—This surveyor evidently used a compass that was quite "off center," as his surveys have to be swung about 4° counterclockwise to fit the ground.

Kahema, Job—Work was poor.

Kalama, S. P.—One of the most reliable native surveyors of that time, with a very extensive knowledge of the names and boundaries of Hawaiian lands.

Kalanikahua, D.—As far as I can learn, not a very reliable surveyor.

Kaona, J.—Surveyed only a few small kuleanas near Honolulu.

Keohokalole, Abraham—Surveyed only a few small kuleanas in Wailuku, Maui; work was revised by Edward Bailey.

Kittredge, Chas. S.—A well trained surveyor; work was not as good as one would expect from his training.

Lyman, Fred. S.—A very careful surveyor.

Lyman, Henry M.—Like his brother, a very careful surveyor; said by C. J. Lyons to have used the average magnetic north in writing out his descriptions.

Lyons, Curtis J.—Perhaps the most careful and conscientious surveyor of that time; used the "average needle" in his descriptions.

Makalena, John W.—Work fairly good, except when he attempted to survey large tracts.

Meyer, R. W.—Said to have been educated in Germany as a civil engineer; a very careful and intelligent surveyor.

Metcalf, Theophilus—One of the good surveyors of that time; described by C. J. Lyons as "a very shrewd and practical man, whose surveys have the merit of always exhibiting and referring to natural features for fixing the lines run." His compass is said by the same authority to have read about 50′ to the east of magnetic north, so that his surveys should be corrected this amount before being run out.

Nahale—Did some surveying in Wailuku, Maui; work revised by Edward Bailey.

Pease, W. H.—One of the most careless and unreliable surveyors of that time.

Pelham, John—Another very unreliable surveyor.

Polapola, John—Only made a few surveys of small pieces; work said to have been fair.

Richardson, George—Work said to have had the same fault as his brother John's (see below); they may have used the same compass.

Richardson, John—Must have used a very defective compass; his distances are good, while his bearings in most cases are quite unreliable.

Rowell, G. B.—Only did a limited amount of surveying at Waimea, Kauai.

Thurston, Asa G.—Work was fair.

Turner, A. F.—Said to have used an English theodolite, and, like James Dillon and Wm. Webster, to have written his notes out in terms of the magnetic north of the initial point. His surveys as a rule fit together and close well, but are not easy to rerun, many of them bearing strong evidence of having been "doctored."

Ua, L. S.—Work was good for a native surveyor; like Kalama and Makalena, Ua had an intimate knowledge of Hawaiian lands and boundaries.

Webster, William—Perhaps the best trained and qualified civil engineer in the islands at that time; a very careful surveyor, using a theodolite and the initial magnetic north.

Most, if not all, of the early native surveyors were trained at Lahainaluna School under W. P. Alexander. While not always reliable, they were never guilty in their kuleana surveys of such grossly inaccurate work as was done by some of the white men. They also had a great advantage over many of the white surveyors in their intimate acquaintance with Hawaiian land matters and the language.

APPENDIX B.

Rate of Change in the Magnetic Declination in Hawaii.

The greatest difficulty in determining the rate of change in the magnetic declination in Hawaii has been, until recent years, the lack of magnetic observations free from instrumental errors. There is available a mass of readings of the magnetic needle at a great many different points on the islands covering intervals of from fifty to seventy years, but these have been made with different instruments and under such diverse conditions that they are almost valueless for purposes of comparison.

Mr. C. J. Lyons reports that in 1853 he "took, with great care, the bearings of a number of well defined mountain summits from a known locality on Hawaii (at Waimea), where no change in the needle would be caused by moving 40 or 50 feet in any direction. In 1872 the same bearings were observed with the same instrument, which at both times was in good order. The difference was 40′, plus on northwesterly bearings and minus on northeasterly." This gives an average annual rate of a little less than 2′, which was adopted and used for many years by the Hawaiian Government Survey. That this rate is too large has been the almost universal experience of local surveyors during the last twenty years.

In March and April, 1873, Prof. W. D. Alexander, Superintendent of the Hawaiian Government Survey, occupied a series of triangulation stations about Pearl Harbor. At most of these stations readings were taken of the magnetic needle. These give the magnetic declination, as determined by the instrument used, at a number of points in a region of coral formation remarkably free of lava rock and from magnetic disturbances of any kind. To get the change of magnetic declination since 1873, the writer, with the same instrument, in April of this year (1920), made careful measurements of the magnetic declination at, or near, six of the stations occupied by Prof. Alexander. The results, which were fairly concordant, gave a weighted mean of 1° 13′ for the total increase in the magnetic declination since 1873, or an average of 1.55′ per annum. This result combined with Mr. Lyons' gives a total increase from 1850 to 1920 of very nearly 2° 00′, as follows:

1850 to 1853, at 2′ per annum	0° 06′
1853 to 1872 (C. J. Lyons)	0 40
1872 to 1873, at 2′ per annum	0 02
1873 to 1920 (Alexander)	1 13
Total	2° 01′

The first magnetic measurements free of instrumental errors were made at various points in the islands by E. D. Preston of the U. S. Coast and Geodetic Survey in 1892.

Similar measurements at some of the same points were made by L. A. Bauer and E. R. Frisby in 1900 and S. A. Deel in 1906. Since 1902 a magnetic observatory has been maintained by the U. S. Coast and Geodetic Survey at Sisal, Ewa, on the extensive coral flat lying between Ewa Plantation and Barber's Point.

From the magnetic measurements made by Mr. Preston in 1892 and Mr. Deel in 1906 the writer has compiled the following table:

Station	Interval	Increase in Declination	Annual Rate
Cocoanut Island, Hilo	1892.6 — 1906.3	27.0′	1.9′
Napoopoo, Hawaii	1892.6 — 1906.3	38.8	2.9
Waimea, Hawaii	1892.5 — 1906.3	21.8	1.6
Lahaina, Maui	1892.6 — 1906.4	19.8	1.4
Kahuku, Oahu	1891.9 — 1906.2	21.6	1.5
Waimea, Kauai	1892.7 — 1906.4	7.4	0.55
Honolulu, Oahu	1892.4 — 1906.2	18.8	1.4

The abnormally large increase in declination in the rocky region of Napoopoo, Hawaii, and the abnormally small increase at Waimea, Kauai, on a rocky bluff, indicate that the environment is not without influence upon the rate of change. Mr. Preston in his report expresses the fear "that local attraction might influence the work" at the Waimea (Kauai) Station. The results from the measurements taken at these places in 1900 are not very concordant and have been omitted.

From the reports of the magnetic observatory at Sisal, Ewa, the following mean annual magnetic declinations and annual changes in declination have been compiled:

Year	Declination	Annual Change	Year	Declination	Annual Change
1902	9° 19.1′ E.		1911	9° 32.2′ E.	0° 02.5′
1903	19.8	0° 00.7′	1912	34.8	2.6
1904	20.9	1.1	1913	37.3	2.5
1905	21.7	0.8	1914	39.6	2.3
1906	23.0	1.3	1915	41.6	2.0
1907	24.3	1.3	1916	43.9	2.3
1908	25.7	1.4	1917	46.3	2.4
1909	27.3	1.6	1918	48.6	2.3
1910	29.7	2.4	1919	50.8	2.2

These results show a steady increase in the annual change in declination up to 1912 and a decrease since then.

The work of the U. S. Coast and Geodetic Survey since 1892 has furnished a scientific basis for correcting magnetic surveys, which will become more and more valuable to local surveyors as time goes on and the results of the magnetic observations at Sisal accumulate.

Seedlings Under Drought Conditions.

At Hamakua Mill Company eight of the so-called "400 Seedlings" and four of 1914 propagations grown under *drought conditions* were cut on July 24-28, 1920, for use as seed in a regular variety test with Yellow Caledonia. H-470 easily led the group of seedlings. The following table gives estimated yields and analysis of the juice:

Var.	Parent	Brix	Pol.	Pur.	Q. R.	Lines	Seed Bags	P. A. T. C.	Estimated Yields* P. A. T. S.
H 470	H 240	20.2	18.84	93.1	6.89	5	45	27.00	3.92
H 469	H 240	20.2	18.07	89.6	7.25	7	56	24.00	3.31
H 472	H 240	19.1	17.66	92.7	7.29	6	48	24.00	3.29
H 471	Str. Mex.	19.0	17.74	93.2	7.28	7	54	23.14	3.18
H 467	H 146	20.8	18.74	89.9	7.00	9	62	20.66	2.95
H 468	Str. Mex.	...	....	...	...	4	28	21.00	...
H 4142	Lah.	21.0	19.51	92.9	6.60	3	19	19.00	2.88
H 4105	Lah.	20.0	18.36	91.8	7.03	7	46	19.71	2.80
H 4174	Lah.	18.6	16.80	90.3	7.77	6	43	21.50	2.77
H 4132	Lah.	19.8	18.70	94.4	6.85	3	16	16.00	2.34

* Lines were 120 feet long. In figuring ton cane per acre, it was assumed that 1 bag of seed per line would give 3 tons cane per acre.

The seed cane was shipped from Honolulu, May 24, 1918, so the seedlings were about 26 months old.

Grown under adverse conditions, when the yields of Yellow Caledonia were cut in half the above figures show the behavior of some of the new varieties under unfavorable circumstances.

[W. P. A.]

Liming at Hamakua Mill Co.

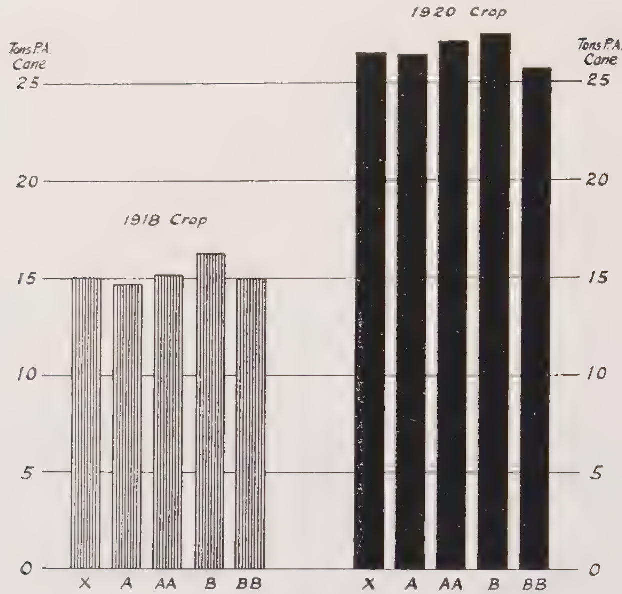
Hamakua Mill Co. Experiments No. 1 *and No.* 2, 1918 *and* 1920 *Crops.*

In these two tests the comparative value of varying kinds and amounts of lime was studied. The cane involved was D 1135, second ratoons, long. The experiments are located in Field 19, at an elevation of 2100 feet. Both of the crops harvested suffered from drought, especially the 1918 crop. All the plots in these tests received uniform fertilization by the plantation.

The lime was applied in October, 1916, for the 1918 crop. Since then no further applications of lime were made.

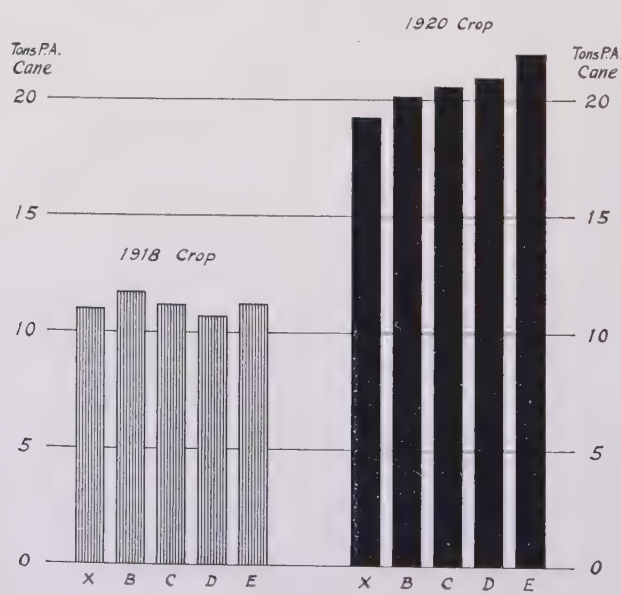
The lime treatments to the various plots, and tabulated results are as follows:

LIME EXPERIMENT
Hamakua Mill Co. Exp.*1, 1918 & 1920 Crops
Comparing Various Forms and Amounts.



X = No sand or lime.
A = 2 tons sand.
B = 2 tons ground lime rock.
AA = 4 tons sand.
BB = 4 tons ground lime rock.

LIME EXPERIMENT
Hamakua Mill Co. Exp.*2, 1918 & 1920 Crops
Comparing Various Forms & Amounts.



X = No lime.
B = 2 tons ground lime rock.
C = 1 ton quick lime.
D = 3½ tons quick lime.
E = 7 tons ground lime rock.

EXPERIMENT NO. 1.

Plots	Treatment*	Yields per Acre					
		1918 Crop			1920 Crop		
		Cane	Q. R.	Sugar	Cane	Q. R.	Sugar
A	2 tons sand	14.7	7.82	1.88	26.4	7.65	3.44
Adj. X ...	No sand	15.4	7.74	1.99	25.4	7.54	3.37
B	2 T. ground lime rock	16.3	8.03	2.03	27.5	7.41	3.71
Adj. X ...	No ground lime rock	15.6	7.76	2.01	28.4	7.53	3.77
AA	4 tons sand	15.2	8.00	1.90	27.1	7.50	3.60
Adj. X ...	No sand	14.5	7.75	1.87	26.6	7.54	3.53
BB	4 T. ground lime rock	15.0	7.90	1.90	25.7	7.60	3.39
Adj. X ...	No ground lime rock	15.1	7.71	1.96	24.4	7.44	3.28
Avg. of all no lime and sand plots		15.1	7.71	1.96	26.5	7.53	3.52
Avg. of all lime and sand plots ..		15.3	7.93	1.93	26.7	7.54	3.53

* Sand and lime applied October, 1916. None applied for the 1920 crop.

EXPERIMENT NO. 2.

Plots	Treatment*	Yields per Acre					
		1918 Crop			1920 Crop		
		Cane	Q. R.	Sugar	Cane	Q. R.	Sugar
B	2 T. ground lime rock	11.7	8.12	1.44	20.1	8.45	2.39
Adj. X ...	No ground lime rock	11.3	8.25	1.37	20.7	7.89	2.62
C	1 T. quick lime	11.2	8.48	1.32	20.5	7.46	2.75
Adj. X ...	No quick lime	10.8	8.18	1.32	18.6	7.89	2.35
D	3½ T. quick lime	10.7	8.49	1.26	20.9	7.82	2.68
Adj. X ...	No quick lime	11.3	8.25	1.37	20.7	7.89	2.62
E	7 T. ground lime rock	11.2	8.30	1.35	21.9	8.13	2.69
Adj. X ...	No lime rock	10.9	8.02	1.36	17.9	7.89	2.27
Average of all no lime plots.....		11.0	8.21	1.34	19.2	7.89	2.43
Average of all lime plots........		11.2	8.36	1.34	20.8	7.91	2.63

* Lime applied October, 1916. None applied for the 1920 crop.

In four years, or during the period of two crops, lime in various forms has not increased the yield of cane in these two experiments sufficiently to make such applications profitable.

In Experiment No. 1, where the comparisons are between treatments of coral sand, a ground lime rock (a preparation which in 1916 was receiving considerable attention) and no lime, the two harvests of 1918 and 1920 give consistent negative results — that is, no increased yields were obtained from the lime plots.

In the 1918 harvest of Experiment No. 2, the different lime treatments produced no increased yield over no lime.

In Experiment No. 2, for the 1920 harvest, when the lime plots are compared with the adjoining check plots, the yields of cane are not consistent. The "C" and "E" plots show slight gains in favor of lime, while the "B" and "D" plots show losses. The average of all the lime plots show a gain of 1.6 tons of cane, or .2 ton sugar.

In Experiment No. 2, an effort was made to add sufficient lime and ground lime rock to neutralize the acidity of the soil. However, soil samples taken in October, 1919, showed that the soils had not been neutralized. The acidity in the "D" plots receiving the heaviest application had been reduced about one-half, while those receiving the less amount showed no decrease in the acidity of the soil.

Details of Experiment No. 1.

Object:

1. To test the effect of lime on acid soils.
2. To compare the value of coral sand and ground Waianae limestone.

Location:

Hamakua Mill Co., Field 19, Section 49.
Elevation of field—about 2100 feet.

Crop:

D 1135 ratoons, long.

Layout:

Number of plots, 32.
Area of plots, each 1/10 acre; consisting of 5 rows, 4.48′x194.4′; lines 3 and 4 to be harvested and lines 1, 2 and 5 to be used as guard rows.

Plan:

APPLICATION OF LIME ON OCTOBER 10 AND 16, 1916.

Plots	No. of Plots	Coral Sand	Ground Waianae Limestone
A	4	2 tons per acre, or 400 lbs. per plot	....
AA	4	4 tons per acre, or 800 lbs. per plot	....
B	4	....	2 tons per acre, or 400 lbs. per plot
BB	4	....	4 tons per acre, or 800 lbs. per plot
X	12	None	None

NOTE:—The fertilization of the experiment carried on by the plantation uniform with the adjoining field.

Experiment planned by L. D. Larsen and W. P. Alexander.
Experiment laid out by W. P. Alexander.
Experiment harvested by W. L. S. Williams.

Details of Experiment No. 2.

LIME EXPERIMENT
Hamakua Mill Co. Exp. #1, 1920 Crop
Field 19. Elevation 2100 ft.

Tons Cane per acre

1 A 29.47	
2 X 28.73	
3 B 29.17	
4 X 31.74	
5 AA 32.15	
6 X 22.51	
7 BB 23.88	
8 X 26.83	
9 A 27.08	
10 X 26.39	
11 B 30.92	
12 X 25.96	21 AA 24.46
13 AA 27.03	22 X 23.54
14 X 21.52	23 BB 22.67
15 BB 25.56	24 X 22.58
16 X 23.79	25 A 21.78
17 A 28.95	26 X 20.13
18 X 29.41	27 B 22.43
19 B Discarded	28 X 24.70
20 X 39.95	29 AA 22.11
	30 X 22.82
	31 BB 30.78
	32 X 33.86

Summary of Pesults

Plots	No. of Plot	Treament	Yields Per Acre		
			Cane	Q.R.	Sugar
X	16	No Lime	26.5	7.53	3.52
A	4	2 tons of Coral Sand	26.4	7.65	3.44
AA	4	4 tons of Coral Sand	27.1	7.50	3.60
B	4	2 tons of Ground Waianae lime stone	27.5	7.41	3.71
BB	4	4 tons of Ground Waianae lime stone	25.7	7.60	3.39
		Average of all lime plots	26.7	7.56	3.53
		Average of all no lime plots	26.5	7.53	3.52

LIME EXPERIMENT
Hamakua Mill Co. Exp. #2, 1920 Crop
Field 19. Elevation 2100 ft

Tons Cane per acre

1 X 18.46	
2 C 21.43	
3 B 20.40	
4 X 22.30	
5 D 20.79	
6 E 21.64	
7 X 18.76	
8 C 20.93	
9 B 24.41	
10 X 21.50	
11 D 21.64	15 B 19.65
12 E 21.71	16 X 22.81
13 X 18.12	17 D 20.56
14 C 19.86	18 E 25.37
	19 X 18.96
	20 C 19.93
	21 B 16.13
	22 X 16.11
	23 D 20.69
	24 E 18.81
	25 X 15.76

Summary of Results

Plots	No. of Plot	Treatment	Yields Per Acre		
			Cane	Q.R.	Sugar
X	9	No lime	19.2	7.89	2.43
C	4	1 ton lime	20.5	7.46	2.75
B	4	2 tons ground lime rock	20.1	8.45	2.39
D	4	3.5 tons of lime	20.9	7.82	2.68
E	4	7 tons of ground lime rock	21.9	8.13	2.69
		Average of all lime plots	20.8	7.91	2.63
		Average of all no lime plots	19.2	7.89	2.43

Object:

1. To compare the value of lime and ground lime rock.
2. To determine the value of different amounts of lime.

Location:

Hamakua Mill Co., Field 19, Section 49.

Elevation of field—about 2100 feet.

Crop:

D 1135, second ratoon, long.

Layout:

Number of plots, 25.

Area of plots, each 1/10 acre; consisting of 5 rows, 4.53′ wide and 192.3′ long. Lines 3 and 4 are to be harvested. Lines 1, 2, 5 are guard rows.

Plan:

APPLICATION OF LIME ON OCTOBER 16–18, 1916.

Plots	No. of Plots	
X	9	No form of lime
C	4	1 ton of lime per acre, or 200 lbs. per plot
B	4	2 tons ground lime rock per acre, or 400 lbs. per plot
D	4	3½ tons lime per acre, or 700 lbs. per plot
E	4	7 tons ground lime rock per acre, or 1400 lbs. per plot

Fertilization of the experiment will be uniform with the adjoining field, and carried on by the plantation.

Experiment planned by L. D. Larsen and W. P. Alexander.

Experiment laid out by W. P. Alexander.

J. A. V. — W. P. A.

Liming Gives Negative Results.

Grove Farm Experiment No. 8—1920 *Crop.*

This was a test comparing the relative value of varying amounts of sand with no sand on an acid, virgin soil. The cane was Yellow Caledonia, plant, on a non-irrigated field. All plots received a uniform application of fertilizer by the plantation together with the surrounding field; this included 500 pounds per acre of reverted phosphate.

The sand was applied broadcast, and harrowed in, after which the field was furrowed and planted. The following amounts of sand were applied:

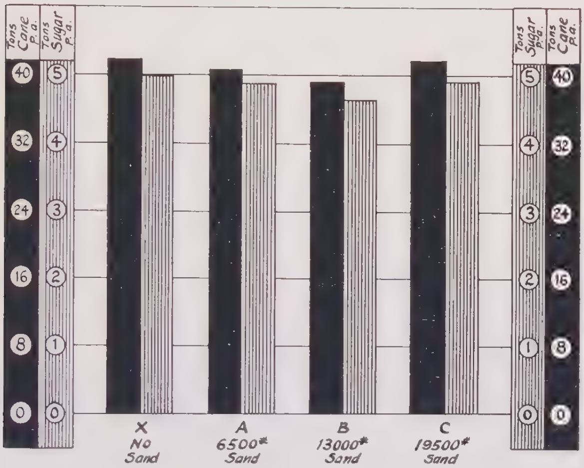
X plots = no sand
A " = 3¼ tons of sand
B " = 6½ " " "
C " = 9¾ " " "

The results of the harvest are given as follows:

No. of Plots	Treatment	Yield per Acre		
		Cane	Q. R.	Sugar
9	No sand	41.9	8.41	4.98
9	3¼ tons of sand per acre	40.7	8.29	4.91
10	6½ tons of sand per acre	39.5	8.45	4.68
10	9¾ tons of sand per acre	42.0	8.52	4.93
Average of all no lime plots		41.9	8.41	4.98
Average of all lime plots		40.7	8.41	4.84

CORAL SAND ON ACID VIRGIN SOIL

Grove Farm Plantation Experiment #8, 1920 Crop



Again we obtain results contrary to popular belief and teachings. That is, these results, as have been the case with a large majority of our lime experiments, show no profitable response to liming. This applies particularly to liming acid soils. In acid soils we have never obtained experimentally any marked increase in yields from liming. On the Island of Oahu, at Oahu Sugar Co. * and at Waipo Substation * we have obtained increased yields from Lahaina and H 109 when liming neutral soils. On the same soil we obtained no response when liming D 1135.

We realize that these tests do not cover the full range of Hawaiian conditions. A number of plantation managers report benefits from liming. This statement of the results of these tests must not be accepted as a general recommendation against liming, but rather as indicating the value of testing the question very thoroughly.

DETAILS OF EXPERIMENT.

SAND VS. NO SAND

Object:

1. To determine the value of sand on acid soil.
2. Amount to apply.

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* See Planters' Record, Vol. XVIII, p. 578.

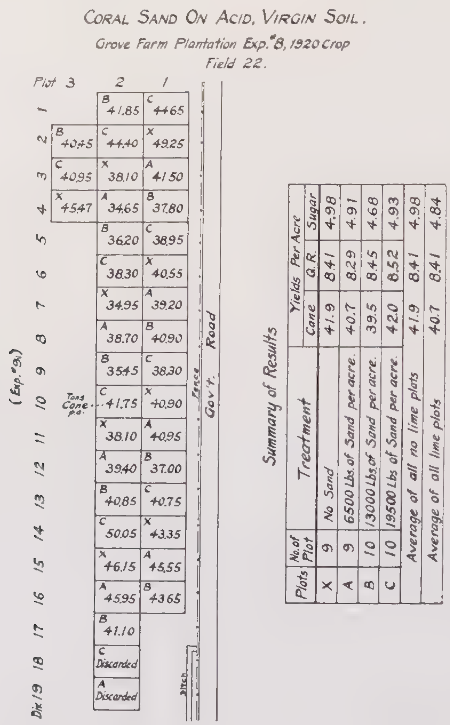
* See Planters' Record, Vol. XV, p. 367.

Location:

Field 22.

Crop:

Yellow Caledonia plant cane on virgin soil, unirrigated.



Layout:

Number of plots = 38.

Size of plots = 1/10 acre (60'x72.5').

Plots composed of 13 straight lines, 4.7'x72.5'.

Plots are separated by 3' roadways running at right angles to the rows.

Plan:

Plots	No. of Plots	Plot Numbers	Lbs. Sand per Acre
X	9	2.1, 3.2, 4.3, 6.1, 7.2, 10.1, 11.2, 14.1, 15.2	......
A	9	3.1, 4.2, 7.1, 8.2, 11.1, 12.2, 15.1, 16.2, 19.2	6,500
B	10	1.2, 2.3, 4.1, 5.2, 8.1, 9.2, 12.1, 13.2, 16.1, 17.2	13,000
C	10	1.1, 2.2, 3.3, 5.1, 6.2, 9.1, 10.2, 13.1, 14.2, 18.2	19,500

After staking out of plots sand was applied, harrowed in, and then the land was furrowed out and planted.

Fertilization to be uniform to all plots.

Experiment planned and laid out by R. S. Thurston.

Experiment harvested, J. H. Midkiff.

J. A. V.

The Status of Lime in Soil Improvement.*

By Elmer O. Fippin.

The use of lime on the soil is shown by practical experience to be needed by such large areas and the scientific questions involved with its correct and economical use are revealed to be of such complicated and far-reaching character that the further investigation of this subject is a matter of major importance in crop production and soil improvement.

The underlying scientific reasons for this need for lime and the functions performed by it in the soil and in the plant are still matters of wide differences of opinion among investigators. This discussion ranges over the questions: Is there free acidity in the soil? What is the relation of free acid to the lime or other base-absorption coefficient of the soil? What tests, if any, constitute an adequate measure of the need for lime by a particular soil for the growth of so-called acid-sensitive crops? Is free acidity in itself the limiting factor or is it correlated with some other condition which is responsible for the character of plant growth, such as the presence of aluminum nitrate?

The opinion is quite general among investigators that the need for lime is associated either in a direct or an indirect way with an acid condition of the soil as measured by the absorption of a base, upon which principle rests most of the methods of measuring the need for lime.

The Use of Lime Materials in the Soil.

Concerning the range of tolerance by different crops of an acid condition of the soil, very little is definitely known, but a wide variation is indicated, for example, by the distinctions between alfalfa and blueberries or red sorrel and red clover. The sorrel plant (12, 14)[1] illustrates a further fact, namely, that some plants have a wide range of tolerance of both an acid and a lime-rich condition of soil, while other plants may have a narrow range of tolerance.

The range of tolerance of microscopic plants such as those concerned with the transformation of nitrogen and those concerned with the production of a diseased condition of plants, such as the potato scab (5) and the club root of cabbage, is equally important from the viewpoint of farm practice. The lack of accurate information concernnig the tolerance of the lower plant forms is equally as great as it is concerning the higher plants. Certain it is that plants cannot be divided sharply into two classes, one of which will thrive only on an alakaline soil while the other will thrive only on an acid soil. We believe that every graduation of tolerance is exhibited among different plants. Herein arises another important point.

Too often it has been assumed that for plants that thrive on a soil near the

* Presented at the twelfth annual meeting of the American Society of Agronomy Chicago, Ill., November 10, 1919, and reprinted in Journal of the American Society of Agronomy, April, 1920.

1 Reference is to "Literature cited," p. 79.

neutral point too much lime carbonate could not be present in the soil. The question might very properly be asked whether the alkaline or calcium-magnesium tolerance of plants may not be quite as important to determine as their tolerance of the opposite or so-called acid condition.

The investigations of Fred[2] of Wisconsin, the studies of chlorosis (4) or inability to absorb iron in certain lime-rich soils in Florida, and field observations by the writer and others point to the importance of this subject.

Effects of Lime on Soil.

Coming now to the use of lime on the soil, including both the caustic and the carbonate forms, two classes of problems arise, namely, (*a*) What are the relative effects of equal amounts of the oxides of calcium and magnesium on the chemical, physical, and biological properties of the soil? and (*b*) What are the relative practical aspects of the use of these different materials?

Several investigations are in progress on the effect of liming materials on the chemical nature of the soil and the soil solution, under laboratory, plat, and field conditions. These have not reached a conclusive stage, as is illustrated by the data on the relation of lime to the availability of phosphorus and to a less extent of potassium (1, 3). Equally undetermined is the ultimate relation of lime to the store of nitrogen in the soil, especially when its use is combined with the growth of a legume.

Much misinformation has been given out on the effect of different forms of lime on the disappearance of organic matter from the soil. Here, distinction has not been made between purely chemical effects of the lime compound on the organic matter and the biological effects resulting from the stimulation of the growth of microorganisms in the soil by lime materials. The growth of such organisms is inevitably at the expense of the organic matter in the soil. To what extent is this effect necessary and legitimate and to what extent may it be undesirable? Is it a similar effect for both carbonate and caustic forms of lime?

The statement, common in the older agricultural literature (8), that caustic lime applied to the soil in even reasonable amounts is especially destructive of organic matter, has usually been put in form to indicate that this destruction is a purely chemical process, such as occurs when spontaneous combustion of inflammable material results from the contract of a large amount of water with a considerable quantity of quick lime. This idea of the destruction of organic matter has extended to hydrated lime, because it also has caustic properties, but it has no capacity for chemical union with water involving the liberation of heat. Further, the slacking of lime in the soil, say as granular quick lime, cannot result in the rise of temperature necessary to a destructive chemical change. Unquestionably there is chemical union of the lime with constituents of the organic matter. That this union is truly destructive of the organic substance, as would be indicated by the liberation, even in strongly alkaline solutions, of carbon dioxide, has not been demonstrated and the phenomena are not in accord with the known principles of organic chemistry.

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[2] Personal communication to the writer.

The chemical and biological relations of this problem must be kept clearly separated. If organic matter decomposes more rapidly where caustic forms of lime have been used than where carbonate forms have been applied, as is frequently claimed, it raises the question whether, as a result of these more active chemical and biological reactions, the use of caustic forms of lime in suitable amounts may be better than the use of carbonate forms. Who can say what are the relative effects of caustic and carbonate forms of lime on the granulation and on the porosity and related properties of different soils? Are these effects the same or do they vary with different kinds of soil? Available data indicate that in any direct way caustic forms of lime have the largest granulating effect (2) on clay soils, while carbonate forms are either nearly inactive or produce positively an unfavorable physical change. Do the available data on this point furnish an adequate guide?

Closely connected here is the question of how long caustic lime remains in the hydrated form in the soil, and into what new combinations either the caustic or carbonate form enters in the soil. MacIntire (11) and Mooers of the Tennessee station have done much work showing, first, that caustic forms of lime are not chemically destructive of organic matter; second, that recarbonation proceeds very rapidly and is normally completed in a few days at the outside; and third, that magnesium and to a less degree high calcium limes rapidly enter in silicate combinations and that these new combinations markedly affect the solubility and movement of those constituents in the soil. Especially does the magnesium seem to increase the movement of sulphur. Conner[3] of Indiana has data showing that calcium in silicate combination, as in basic slag, may be nearly as effective in performing the functions of lime in the soil as when applied in caustic or carbonate form.

Forms and Fineness.

This matter of the value of lime in certain types of silicate and similar combinations is particularly important because it is related to the matter of fineness of lime materials applied to the soil. If lime in these silicate forms of combination is just as effective in affecting the yield of crops as if it were in carbonate form, it is then quite permissible to apply those forms of lime that enter most actively into these new combinations, namely, burnt lime and finely pulverized carbonate, as to use the more inactive coarse carbonate. There may even be an advantage from the formation of these silicates because, first, they suggest the precipitation of colloidal silicates; second, they maintain a more mild alkalinity; and third, they aid in conserving the lime materials in the soil without interfering with their usefulness.

Growing out of this same question of form and fineness is the question of the movement of lime through the soil and the possibility of loss from leaching. The lysimeter data (10) collected at Cornell University during five years do not show any increase in loss of calcium and magnesium when lime is applied. These short-period data are vitiated by the existence of a large amount of limestone in the deep subsoil, which would tend to mask any movement from the surface

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[3] Personal communication to the writer.

soil. MacIntire has found the leaching of lime through a deep section of soil to be essentially independent of the rate of application in any ordinary period of a few years. Let it be noted here that we are not concerned with what may happen in a thousand years, but with what is the practical loss from the vertical soil section that will occur in three, five, or ten years, which is as long a period as the application of lime is intended to cover.

The analysis of the soil of one of the fields at Rothamsted (6) shows the presence of as much as 3.3 per cent of carbonate of lime in the surface 9 inches and none in the second 9 inches. This carbonate of lime seems to be the result of application of chalk so long ago that the record is lost. Its persistence in the soil and the lack of movement into the subsoil indicate how slow is the movement of lime materials.

We come now to the question of suitable fineness of limestone. We have largely disposed of the question of extreme fineness. The next question here is, how large may particles of lime carbonate be and still perform the full functions of such material in the period for which it is applied, namely, from three to six years or for an average rotation? First of all, let us be reminded that certain processes in the soil are inhibited, as compared with their operation in a free liquid. This is especially true of diffusion. Lime carbonate is soluble in an acid solution, and will continue to dissolve as long as the acid is present in contact with the material. In the soil, the question arises, through how wide an area of soil does diffusion operate when this soil is in the optimum moisture condition? From most of the investigations available it seems to be very slow, and to reach a very short distance from the point of solution. If there is more lime in a particle than is required to neutralize the acid solution or satisfy the lime-absorption coefficient of the soil within the active range of the surface of the lime particle, then at the end of this reaction the remainder of the particle of lime will be essentially sealed in a shell of the alkaline soil where it may remain for a long period except as it is disturbed by mechanical means. How coarse may a particle be before this condition occurs in the average acid soil? Is the maximum size of such a particle as large as one-fourth or one-tenth of an inch in diameter, or is it down around one-fiftieth to one-eightieth of an inch in diameter? The practical data on this point are very meager. Observations on calcareous glacial soils reveal particles of carbonate of lime in soils the greater part of which are distinctly acid to litmus and which respond with larger crop growth where lime is applied. Experimental field data (7, 9, 13, 15) are available for so short a period or have been secured under such conditions of soil, crop succession, and rate of application as to make them of questionable value as a guide in this practical matter. Certain it is that such studies are not adequately conducted unless four conditions are met:

1. The soil must be distinctly in need of lime throughout a vertical section at least 4 feet deep from the surface.

2. The limestone must be sorted into rather narrow textual divisions and used in oxide-equivalent amounts.

3. The rates of application should range from a very small quantity, such as 200 or 300 pounds, up to as large a quantity as several tons.

4. The crop should be one sensitive to an acid soil condition and one not able to succeed in that soil without lime.

A fifth condition may be added, namely, insurance that there is an adequate supply of nutrients such as phosphorus. The question of suitable fineness cannot be regarded as settled in any sense, nor is it sufficient to advise the use of a large quantity of coarsely ground material on the chance that there may be enough fine material to supply the needs of the soil for good plant growth. This runs into economic questions A further point involved is the extent to which the time element may compensate for lack of fineness.

Field Experiments at the Present Time.

Almost none of the field experiments involving the study of lime materials is designed in a way adequately to investigate any one or more of the important scientific and practical problems involved in the use of liming materials on the soil. Certainly no adequate data of that sort have accumulated This is not meant to cast any undue reflection on such carefully maintained or long continued work as that at the Ohio, Pennsylvania, and other stations. In the planning of those experiments the natural human limitation attaching to the investigations in a new field has been involved.

Relation of Form of Lime to the Type of Soil.

The questions of caustic vs. carbonate lime, fine vs. coarse lime, calcium vs. magnesium, and the amount of lime necessary for particular crops have not been settled by scientific investigations and for the guidance of practice must rest largely on the empirical results of field trials. Such empirical or practical field data as well as real experimental work should include results obtained on a number of types of soil. It is not safe to draw conclusions from results on a single type of soil.

Finally, the practical aspects of these questions are embodied in laws covering the sale of liming materials, which are now widely divergent in procedure and requirements, and reflect the unsettled state of the general knowledge on the subject. Certainly, the essential elements of a lime-inspection law must be very much the same in the different States. If it is oxides of calcium and magnesium with which the farmer is concerned, then the first step would seem to be to report all forms of liming materials, both carbonate and caustic, on the basis of their oxide content. If fineness is a factor in value, then the fineness of carbonate materials should be reported for a standard series of screens ranging in size from the coarsest material that has appreciable value down to as fine materials as seems to be of importance under field conditions. The United States Bureau of Standards has recently promulgated a new system of specifications for testing screens, and all provisions for screen analysis should be in harmony with these specifications and uniform among the different States.

I hope that the information, energy, and facilities of all the workers in the field of soil and crop improvement may be pooled in some kind of a broad conference to study all these questions, and as rapidly as possible to standardize our information and practices with reference to the use of lime in soil.

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[W. P. A.]

Effect of the Relative Length of Day and Night and Other Factors of the Environment on Growth and Reproduction in Plants.

Messrs. W. W. Garner and H. A. Allard[1] have shown that relative length of day and night has been found to exert a remarkable influence on growth and reproduction in a number of different plants which have been studied. The work was done near Washington, D. C., where the summer days are long. Plants were grown in wooden boxes, galvanized iron buckets, or ordinary flower pots, depending on the size and growth habits of the species in question. Test plants were placed in a dark house for a portion of each day, while controls were kept outside and exposed to the full day period of illumina-

[1] "Journal of Agricultural Research," Vol. XVIII, No. 11, Washington, D. C., March 1, 1920.

tion. Most test plants were exposed to light for five, seven or twelve hours daily. Those exposed for five hours were taken from the dark house at 10 A. M. and returned to the dark house at 3 P. M. daily. Those exposed for seven hours were taken from the dark house at 9 A. M. and returned at 4 P. M., while those exposed for twelve hours were taken out at 6 A. M. and returned at 6 P. M.

Soybeans, tobacco, wild asters, beans, carrots, lettuce, radishes, and a number of other plants were tested. It was found that each species, and, in fact, each variety, can attain the flowering and fruiting stage only when the length of the day falls within certain limits. Rate of vegetative growth is directly proportional to the length of the daily exposure to light. Light intensity within certain broad limits does not seem to be a factor of much importance. How greatly the rate of growth may be influenced by shortening the daily period of illumination may be seen from the following table, which summarizes some of the results obtained with four varieties of soybeans. The heights given in the table are based on measurements of twenty to twenty-five plants in each case.

TABLE SHOWING HOW GROWTH OF SOYBEANS IS CHECKED BY SHORTENING DAILY PERIOD OF ILLUMINATION

Variety	Duration of Test	Height of Plants Illuminated for:			
		5 Hours Daily	7 Hours Daily	12 Hours Daily	Full Day
Mandarin	May 20 to June 15	6–7 in.	....	....	18–20 in.
Mandarin	May 20 to June 15	....	9–10 in.	....	19–20 in.
Mandarin	June 11 to July 21	....	....	14–15 in.	32–33 in.
Peking	May 20 to July 21	5–6 in.	....	....	42–43 in.
Peking	May 20 to July 21	....	8 in.	....	45–48 in.
Peking	June 11 to Aug. 6	....	....	14–15 in.	39–40 in.
Tokyo	May 20 to July 29	7–8 in.	....	....	49–50 in.
Tokyo	May 20 to July 29	....	7–8 in.	....	49–50 in.
Tokyo	June 11 to Aug. 21	....	....	17–18 in.	42–43 in.
Biloxi	May 20 to Sept. 4	6–7 in.	....	....	57–58 in.
Biloxi	May 20 to Sept. 4	....	11 in.	....	57–58 in.
Biloxi	June 11 to Sept. 8	....	....	23–24 in.	54–55 in.

It will be seen from the table that shortening the natural period of illumination, and thereby the working day of the soybean plant, greatly reduces its rate of growth.

The variety Mandarin is early maturing; Peking, medium maturing; Tokyo, late maturing; and Biloxi, very late maturing. For plantings in the field extending through the month of May, the average number of days from germination to blossoming was approximately 27, 56, 70 and 105, respectively, for Mandarin, Peking, Tokyo and Biloxi. Under the influence of a daily exposure to light of twelve hours or less, all of these varieties became early maturing. In

other words, it seems that the reason Mandarin is an early variety, and Biloxi a very late variety, is to be found in the fact that Mandarin attains the reproductive stage under a long daily period of illumination, while for Biloxi a short daily period of illumination is necessary before it will blossom. Mandarin comes to blossom during the long days of June and July. The short days of September are required to bring Biloxi to flower. If the length of day is artificially shortened, Biloxi also will blossom during June and July.

The other plants studied gave similar results. It seeems that sexual reproduction can be attained by plants only when they are exposed to a specifically favorable length of day. It is thought that relative length of day through the year is an important factor in determining whether many plants behave as annuals, biennials, or perennials. It is also thought to be an important factor in determining the natural distribution of plants. The effect of the relative length of day on the time of blossoming of cultivated plants is an important factor in crop yields. It emphasizes the importance of seeding at the proper time.

[L. O. K.]

Notes on Double Polarization Methods for the Determination of Sucrose and a Suggested New Method.*

By Geo. W. Rolfe and L. F. Hoyt.

The well-known principles and methods of double polarization applied in the analysis of commercial sugar products need not be detailed here. The methods in use depend on the assumption that the change in optical rotation of a sugar solution, which is the measure of the sucrose, is the result of the inversion of the sucrose only. One of the chief objections to the original method of Clerget and Herzfeld arises from the fact that the direct reading is made on a practically neutral solution and the invert reading on a strongly acidulated one. Much work has been done in developing improved methods of procedure to prevent or at least mitigate the errors which are introduced under these conditions, especially in sugar estimations of low-grade products where the change in acidity causes changes in the optical rotation of the sugars, other than sucrose, which are present. Those who are interested in these investigations may be referred to the voluminous and familiar papers of Pellet, Sidersky, Anderlik, and others. As the field has by no means been exhausted, even so far as to develop methods which really meet many of the requirements of commercial analysis and general research, the present paper is published as suggestive of a new line of attack of the problem.

In making up the solutions two lots of commercial granulated sugar were

* Journal of Industrial and Engineering Chemistry, March, 1920.

used—one from the Standard Refinery of Boston, polarizing 99.95 and the other from the Revere Refinery, polarizing 99.99. The factors of inversion for these sugars were obtained by the Clerget method, modified by carrying out the inversion at room temperature, and by the method of Herzfeld, likewise modified. Table I gives these factors (see also Table II).

TABLE I.

Method	Sugar Used.	Time. Hours.	Temperature ° C.	Factor
Clerget	Standard Granulated	22.0	23	144.56
	Revere Granulated	22.0	28	144.17
			Average	144.37
Herzfeld	Standard Granulated	21.5	28	142.43
	Revere Granulated	21.5	28	142.67
			Average	142.56

It is well known that the factor obtained by the invertase method of Hudson is much lower than that obtained by the Clerget and similar procedures, and it is also known that this is caused by the fact that the acid augments the invert reading. What does not seem to be so well known, if it has been published at all, is that *neutralized* acid-inverted solutions give larger readings than the original acid solutions. Apparently neutralization does not affect the increase in rotation caused by the acid, but the reading is still further increased by the salts formed in neutralization as shown in Table II.

TABLE II.

(Method of Herzfeld.)

Test.	Factor for Acid Solution.	Factor for Neutralized Solution.	Difference.
1	142.43	143.30	0.87
2	142.69	143.39	0.70
3	142.66	143.41	0.75
		Average	0.77

An invert-sugar solution, made by heating a $N/2$ (saccharimetric) sucrose solution with 0.01 normal hydrochloric acid on a boiling water bath for 30 min., gave the factor 141.7, agreeing with that given by Browne for a neutral solution, as was to be expected, since the acidity was negligible. Adding hydrochloric acid in the proportion used in the Herzfeld method increased the reading by —1.35. Addition of the equivalent amount of sodium hydroxide to produce a neutral solution, gave a further increase of —0.60.

Some work was done with the modification of Anderlik, in which urea is used as a retardant of the inversion when the direct reading is made in the presence of the usual amount of hydrochloric acid. Our experience with this method on cane products was unsatisfactory, as the direct polarization changed rapidly and indeed was quite unmanageable when the temperature approached 26°. This method, therefore, would be inapplicable in raw-sugar work in the tropics,

however satisfactory it may be for low-grade beet products. Our tabulated results, which are not given here since the method has already been adversely criticized by Browne and others, show that unless the direct polarization is completed in less than 3 min. the error from inversion change is too great to be negligible. Glycocoll as a substitute for urea proved still more unsatisfactory.

Inversions With Mono– and Trichloroacetic Acid.

It seemed desirable to find a substitute for hydrochloric acid which would invert so slowly at ordinary temperatures as to permit direct readings without error, and yet be sufficiently acid to effect complete inversion upon convenient heat treatment. Accordingly, the following investigations were made with mono- and trichloroacetic acids, which had the great advantage of giving no troublesome precipitate with the soluble lead salts which were left after clarifying. The affinity constant of trichloroacetic acid is given as 75.4 and that of monochloroacetic acid as 4.8 on the basis of HCl = 100.

TABLE III.
Direct Saccharimeter Reading.

With 0.5 G. Trichloroacetic Acid.			With 0.5 G. Monochloroacetic Acid.	
Time Min.	Reading.	Temperature ° C.	Time Min.	Reading.
3	50.00	19.2	5	50.00
5	50.00	19.3	6	50.00
7	50.00	19.4	8	50.00
10	50.00	19.6	10	50.00
15	50.00	19.3	15	50.00
20	49.90	20.4	20	50.00
30	49.75	20.6	30	50.00
40	49.70	20.9	45	49.85
60	49.55	21.4	60	49.80
90	49.30	21.6	25 hrs.	47.50

(13.0 g. of sucrose in 100 cc.)

The first series of experiments (Table III) was to determine the rates and factors of inversion at ordinary temperatures of half (sugar) normal solutions of sucrose containing 0.5 g. of mono- and trichloroacetic acids, respectively. These two solutions were heated in stoppered flasks for 30 min., in a boiling water bath, and inverted smoothly without discoloration, giving constants of 142.2 in both cases.

These inversions of pure sucrose solutions of commercial concentration promised a satisfactory method, but Tolman's observations on citric acid inversions have shown that soluble acetates have a marked inhibitory effect. It was calculated that 1 cc. of lead acetate (sp. gr. 1.26) would leave soluble acetate equivalent to 0.125 g. of sodium acetate. A half (sugar) normal solution of sucrose was therefore made up with 0.5 g. of monochloroacetic acid and 0.625 g. of sodium acetate, the latter equivalent to 5 cc. of lead acetate, which was considered the maximum for all ordinary commercial polarizations. It was found that acetate in this amount retarded inversion in the cold to such an extent that

there was no change in the direct reading for several hours, and even 30 min. treatment at 100° gave only 15 per cent inversion. The retarding influence of the soluble acetate could be overcome by increasing the amount of chloroacetic acid, but in the case of trichloroaçetic acid this was not practicable because, if enough acid was used to complete the inversion of a $N/2$ solution, it gave a reading of 49.90 after only 4 min. in the cold.

Two grams of the trichloro-acid in the presence of 0.625 g. of soluble acetate caused an inversion of only 94.3 per cent in 30 min., 3 g. being necessary for complete inversion.

With the soluble acetate omitted, 3 g. of trichloroacetic acid accelerated the inversion in the cold as shown.

$N/2$ solution, polarizing 50.00.	
At end of 5 min....................	49.85
At end of 10 min....................	49.75
At end of 25 min....................	49.60

Furthermore, the trichloroacetic acid, decomposing in the water bath, frequently gave off so much chloroform vapor as to burst the flasks. With monochloroacetic acid there is a slight depression of the polarization caused by the addition of the acid and acetate, as a similar $N/2$ sugar solution at the end of 2 min. gave a reading of 49.85 which remained constant through observations of a few minute intervals carried on for over an hour.

A sample of Cuban sugar, clarified with 2 cc. standard basic lead acetate solution per $N/2$ weight and treated with 3 g. of monochloroacetic acid, gave a constant polarization for over an hour.

TABLE IV—EFFECT OF ACETATES ON INVERSION FACTOR OF A $N/2$ (SACCHARIMETRIC) SOLUTION OF SUCROSE INVERTED BY 3 G. OF MONOCHLOROACETIC ACID AT 100° C.

Sodium Acetate per 100 Cc. G.	Time of Heating Min.	Average Value Inversion Factor	No. of Observations.
None	30	141.02	10
0.0625	30	141.00	5
0.125	30	141.05	4
0.325	30	141.10	1
0.500	30	141.00	5
0.625	30	140.32	4
0.625	60	141.06	3

To test the effect of an excess of lead acetate clarifier, a $N/2$ sucrose solution to which had been added 1 cc. of lead acetate clarifier, 0.5 g. of sodium acetate, and 3 g. of monochloroacetic acid, was found to resist inversion for 30 min. in the cold but inverted smoothly in the boiling water bath in 30 min. with no signs of discoloration, the inversion factor being identical with that of a lead-free solution similarly treated. Table IV shows the influence of varying amounts of sodium acetate on the inversion factor obtained with monochloroacetic acid. It will be seen that the inversion is incomplete after 30 min. boiling in the presence of more than 0.500 g. of soluble acetate.

To test the effect of sodium chloride two inversions with monochloroacetic acid were made in the way described in the above series, one with 0.625 g. of acetate and 0.65 g. of sodium chloride, the other with 0.65 g. of sodium chloride only. The factors obtained were 141.04 and 141.08, respectively, showing that a sodium chloride content up to 5 per cent of the weight of the sample does not affect the inversion.

Whenever sugar solutions are inverted at a high temperature with hydrochloric or monochloroacetic acid there is a noticeable lag in the polarization even after the solution has reached temperature equilibrium with that of the saccharimeter, the constant reading being always (numerically) greater than the initial. This lag, usually lasting but a few minutes, has been repeatedly noticed in solutions treated by the Clerget and Herzfeld methods, and is greater the less the acid content. When $N/100$ HCl was used the initial polarizations were as much as two divisions lower numerically than the final constant value. With chloroacetic acids the lag is smaller but it lasts longer (Table V). The possible causes of this lag will not be discussed at this time.

TABLE V—LAG OF POLARIZATION OF VARIOUS INVERTED SUGAR SOLUTIONS.

A			B			C		
Time Min.	Reading.	Temp. Deg.	Time Min.	Reading.	Temp. Deg.	Time Min.	Reading.	Temp. Deg.
6	11.50	18.6	7	13.50	19.8	5	12.00	19.4
7	12.20	18.8	8	13.90	19.8	6	12.75	19.5
9	13.00	19.7	9	14.30	20.0	8	13.60	20.0
10	13.15	20.2	10	14.50	20.3	10	14.20	20.4
12.5	13.50	21.0	12	14.70	20.8	15	14.85	20.8
15	13.80	21.4	15	14.85	21.3	20	14.95	21.2
30	14.15	21.4	20	14.90	21.6	30	14.85	21.7
60	14.40	23.2	30	14.80	22.0	100	15.35	22.0
			Hrs.			Hrs.		
75	14.30	23.0	20	15.85	20.0	18	16.10	20.0
100	14.00							
Hrs.								
20	15.20							

D			E		
Time Min.	Reading.	Temp. Deg.	Time Min.	Reading.	Temp. Deg.
6	13.60	22.1	3	12.70	21.4
10	14.10	22.4	4	13.25	21.5
15	14.30	22.4	5	13.55	21.7
27	14.85	22.6	7	14.05	22.2
40	14.70	23.6	14	14.35	22.6
Hrs.					
23	15.80	20.0	25	14.50	23.2
			40	14.50	23.5
			Hrs.		
			2.25	14.50	23.5
			4	15.10	23.6
			24	15.76	20.0

A—$N/2$ Sucrose solution inverted by 0.01 per cent HCl at 100°.
B—$N/2$ Sucrose solution inverted by 0.01 normal HCl at 100°.
C—$N/2$ Sucrose solution inverted by 0.5 g. trichloroacetic acid at 100°.
D—$N/2$ Sucrose solution inverted by 3 g. monochloroacetic acid with 0.625 g. of $NaC_2H_3O_2$.
E—$N/2$ Sucrose solution inverted by 3 g. monochloroacetic acid and 0.625 g. of $NaC_2H_3O_2$.

The factor 141.0 has been adopted as correct for a monochloroacetic acid inversion, and is based on the series of inversions of pure sucrose shown in Table VI. The 60 min. inversions showed some decomposition, as indicated by the lower factor. If, however, low-grade products, requiring as much as 5 cc. of clarifier, are inverted, the time should be increased to 1 hr., owing to the retarding influence of the soluble acetates. This is made clear in Table IV.

TABLE VI—DETERMINATION OF INVERSION FACTORS BY THE MONOCHLOROACETIC ACID METHOD.

	15 Min.	30 Min.	60 Min.
	141.60	141.14	140.30
	140.08	140.92	140.38
	141.20	140.90	140.40
	140.98	140.90	140.20
	141.16	141.00	.....
Average ...	141.20	140.97	140.32

To compare this method with the invertase method of Hudson, accepted as the standard method for accurate results, an invertase solution was prepared from compressed yeast. Half-normal sugar solutions were inverted at about 30° C. with varying amounts of this solution. The results are given in Table VII.

TABLE VII—INVERSION CONSTANTS BY INVERTASE METHOD OF HUDSON.

Time of Inversion.	Factors for Volume of Invertase Solution Used.		
Hrs.	5 cc.	7.5 cc.	10 cc.
21	140.46	141.54	141.68
45	141.54	141.34	141.72
70	141.70	141.72	.....

Time permitted only comparative tests by the invertase, Herzfeld and monochloroacetic methods on two samples of Cuba seconds and one of refinery barrel syrup. In the invertase tests the solutions were carefully "deleaded" according to directions by Browne.[1] In the other tests the minimum amount of basic lead acetate to clarify was used. Table VIII shows the comparative results by the three methods, making it clear that the monochloroacetic acid method gives results much closer to those obtained by the standard invertase method than does the Herzfeld method.

[1] "Handbook of Sugar Analysis," p. 276.

TABLE VIII.

A—Comparison of Double Polarization Methods.

Sample.	Method.	Direct Polarization.	Concentration of Solution.	Invert Polarization. (All Readings in $N/2$ Solution.)	Factor Used.	Per Cent of Sucrose.
Cuban Second Sugar No. 1438	Invertase	88.01	N	—14.10	141.70	88.24
	Monochloroacetic	44.44	$N/2$	—13.51	141.00	88.45
	Herzfeld	89.01	N	—14.38	142.66	88.63
Cuban Second Sugar No. 1323	Invertase	88.40	N	—11.18	141.70	84.08
	Monochloroacetic	44.00	$N/2$	—11.26	141.00	84.36
	Herzfeld	88.23	N	—12.16	142.66	85.04
Barrel Syrup from Am. Sugar Refinery	Invertase	34.63	N	—6.65	141.70	36.35
	Monochloroacetic	17.39	$N/2$	—6.46	141.00	36.41
	Herzfeld	35.02	N	—6.93	142.66	36.85

B—Percentage Difference between Per Cent of Sucrose by Three Methods.

Sample.	Monochloroacetic minus Invertase.	Herzfeld minus Invertase.	Herzfeld minus Monochloroacetic
Cuban Second No. 1438	0.21	0.39	0.18
Cuban Second No. 1323	0.28	0.96	0.68
Barrel Syrup	0.06	0.50	0.44

The effect of the monochloroacetic acid method on commercial glucose readings was briefly investigated.

Many analysists do not realize that commercial glucose is not a well-defined chemical compound, but may vary considerably in composition and physical characteristics. The average glucose of today is considerably lower converted than that of a few years ago, so that the Ventzke reading of 175 for the (sucrose) normal weight under standard conditions of polarizing is too low. In fact, the sample of glucose used in the present investigation showed a Ventzke reading of 177.85.

TABLE IX—EFFECT OF MONOCHLOROACETIC ACID ON COMMERCIAL GLUCOSE READINGS IN DOUBLE POLARIZATION METHOD.

Test Made.	Readings with No Acid.	*Readings with 3 g. Monochloroacetic Acid.	Difference.	Total Difference.
Before heating	(*a*) 88.70	(*b*) 88.10	$(a-b)=0.60$	1.89
After heating	88.09	(*c*) 86.81	$(b-c)=1.27$	....
Before heating	(*a*) 88.49	(*b*) 88.05	$(a-b)=0.44$	1.99
After heating	88.50	(*c*) 86.85	$(b-c)=1.50$	....
Before heating	(*a*) 88.52	(*b*) 87.98	$(a-b)=0.54$	1.85
After heating	88.53	(*c*) 86.67	$(b-c)=1.31$	....
				Average 1.88

Table IX shows the polarization effect of monochloroacetic acid, as used in the double polarization method described, on an approximately 10 per cent solution of this glucose.[2]

Summary.

The following double polarization method is suggested as a result of these investigations. Dissolve the normal weight of sample in a 100 cc. flask, clarify with an appropriate amount of lead acetate, make up to volume and filter (the usual procedure for commercial polarizations). Transfer 50 cc. of filtrate to a 100 cc. flask, add 15 cc. of a 20 per cent solution of monochloroacetic acid, make up to volume with water, and polarize within 15 min. after adding the acid. To invert, transfer about 50 cc. of the solution to a 50 cc. flask, stopper tightly by tying down the cork, and immerse flask in boiling water, maintaining active ebullition for 30 min., or for 60 min. for low-grade products clarified with a large amount of lead acetate. Remove flask, and cool quickly to room temperature. Allow to stand at least 2 hrs. and polarize in 200 mm. tube with thermometer.

$$S = \frac{2(a-b)}{141 - \frac{t}{2}} \times 100$$

$S =$ Per cent Sucrose. $b =$ Invert reading.
$a =$ Direct reading. $t =$ Temperature.

All solutions should be made and polarized as nearly as possible at 20°.

The advantages of this method are:

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2 Weber and McPherson's investigations. (J. Am. Chem. Soc., 17 1895), 312, 320.

I—Direct and invert readings are made on a solution of unchanged acidity and sugar concentration.

II—Excess of basic lead acetate, equivalent to one cc. in a half (sugar) normal solution, does not affect the inversion or produce troublesome precipitates.

III—It gives more accurate results than the Herzfeld method.

IV—Inverted solutions of low-grade products are lighter in color than those inverted by the Herzfeld method, and therefore easier to polarize.

V—No error is introduced by making up to volume after inversion.

The chief disadvantage seems to be the time required, but this is less than that required by the invertase or the more rational modifications of the Clerget and Herzfeld methods in which the inversion is carried out at room temperature, which requires at least 22 hrs. The actual time required in manipulation is little, if any, more than that taken by the usual methods.

[W. R. M.]

Recent Work of the Rothamsted Experimental Station.

By Guy R. Stewart.

There is no institution that makes a greater appeal to the interest and imagination of the agricultural worker than the Rothamsted Experimenal Station at Harpenden, England. This unique organization was founded by John Bennet Lawes, who began experiments on his estate about 1834. In 1843 systematic field experiments were commenced, and Joseph Henry Gilbert was engaged as chemist and director. He continued in his association with Sir John Lawes till his death in 1901. The relations of these two students of agriculture were wonderfully close and cordial. Together they planned the experiments which were to be carried on far into the future.

On some of the experimental plots the same scheme of planting and fertilization has been followed from 1843 to the present day. Certain rearrangements were made on a portion of the fields in 1852, but even so they are by far the oldest experiments in existence.

The Rothamsted Station has never been connected with any other organization. For a long period it was maintained entirely by Sir John Lawes. In 1889 he formed a trust for the continuance of the investigations, setting apart for that purpose the laboratory which had been built by public subscription and presented to him, the land on which the experimental tracts were located, and a trust fund of 100,000 pounds.

Since that time various private gifts have been made to the station, as well as certain grants from the Board of Agriculture, for the investigation of special problems.

The purpose of the institution has always been to study the fundamental relations of the soil and the crop. Even though its work has been planned to study the underlying scientific principles upon which agriculture is based, the Rothamsted investigations have constantly been of enormous practical value to the agriculturist.

The last triennial report, which reached us during the past year, has many suggestive items in its pages. Two-thirds of the station's staff had joined the army or entered the Government service during the early period of the war. Women were engaged to take the places of many of the men, and so the more important lines of investigation were carried on, and new emergency problems were undertaken. A long and varied list of inquiries was referred to the station by various governmental agencies. These covered reclamation schemes, fertilizer problems, utilization of waste material, and food production problems. The long time investigations were not neglected, but four major lines of work were taken up to handle the immediate questions. These groups were, (1) the economical use of manure, (2) the plowing up of grassland, (3) the control of soil organisms, and (4) the nutrition of plants. The results obtained on all these lines are of permanent interest and value for scientific agriculture.

Barnyard manure has been the most important fertilizer in Europe for many generations. It is believed that 37,000,000 tons per annum are made in Great Britain, with a cash value of at least $55,000,000. Previous work has shown that approximately half the nitrogen was ordinarily lost in storage and handling. Two causes were found to operate, namely, exposure to the weather, and deterioration from the air that penetrated into the heap.

In previous investigations, barnyard manure has been studied mainly as a source of nitrogen, but in the work carried out at Rothamsted it was found that this was too narrow a view, and that the organic matter plays an imporant part.

A considerable part of the manure heap is made up of straw, which, farmers have generally recognized, must undergo a certain amount of decomposition before the best results could be obtained. It was now found that the unchanged straw goes far to neutralize the benefits of the other fertilizing materials, and in extreme cases it may actually decrease the crop. Changes and fermentation in the cellulose and carbohydrate constituents were found to be essential to its fertilizing value.

This dependence upon manure as the principal farm fertilizer is only possible under a system of diversified farming. The most progressive American farmers have attempted to supply the nitrogen and organic matter which the English farmer obtains from manure by the use of cover crops. Excellent results have been obtained from these crops where they have been turned under in a fresh succulent state. Owing to the shortage of rainfall that often occurs in the semi-arid western states, some farmers have tried dry straw to supply organic matter. The general result has been a distinct reduction of fertility that

corroborates the Rothamsted manure experiments. It is quite possible in the Hawaiian Islands that some of the decrease in yield experienced in the drier regions, when cane trash is turned under, may, in the same way, be due to the harmful effect of the undecomposed woody tissue.

The problems connected with the breaking up of grassland, which took place in England during the war, produced a number of interesting points. Insect pests, such as wireworms, developed in astonishing numbers, so that soil sterilization by heat was found to be necessary for their control, though this was only feasible for high-priced truck crops.

The weed flora began to give immediate trouble. The land plowed up had been in grass for ten years, but careful experiments showed that the lower layers of the soil, to a depth of at least twelve inches, contained vital weed seeds. Studies were then made of land thirty years under grass, and it was found to produce a copious crop of weeds. Land sixty years in grass gave a smaller number of weeds, while land two hundred years in grass produced none at all.

Studies were also made of the losses in stored-up fertility of grassland when cultivated. Here it was found that just as with virgin soils, the greatest loss of fertility was due to the oxidization and changes caused by cultivation, and that this loss was greater than the plant food removed by the crop.

The work on problems of the soil bacteria have shown an interesting relationship between the numbers of bacteria and protozoa. It has been found that the protozoa multiply at the expense of the bacteria, and that when this was the case the soil became unhealthy for plants. Certain truck garden and hot house soils showed this trouble, and it was found that it could be remedied by soil sterilization.

In the field of plant nutrition, numerous papers have recently been published from the Rothamsted station. These bear directly on the fundamental relationship of the plant to the soil. They take up the concentration of the medium best suited to plant growth. Other studies present information as to the formation of carbohydrates in root crops. Cane sugar was the sugar first formed in the leaves. This was transformed into simpler sugars in order to permit its transfer to the root, and again converted into cane sugar for storage.

Reference to the future plans of the Rothamsted Station clearly show the relationship it bears to the practical problems of English agriculture. The director points out that since the farmer's task in the future will be to increase his yield, the problems connected with this will necessarily determine the program for future research work. Some of the questions that relate to wheat production are now being faced by the station. "We must strengthen the straw, improve the tillering, regulate to some extent the development of grain, and control the pests. Until these are all solved, we cannot hope to get much further with increased wheat yields."

Such a record of accomplishment and constructive planning for the future is inspiring to us, even though we do not face the varied questions of diversified farming, and are far distant from the disturbing problems of Europe.

Low-Grade Sugar Cane Molasses.*

By W. H. Dalrymple.[1]

There is, perhaps, no stock-feeding material that has aroused so much general interest among stockowners and feeders in this country as low-grade sugar-cane molasses, or "blackstrap." And, as inquiries concerning this material have become so numerous, from all over the country, the publication of a short article on the subject, setting forth its main features as a feed, has been deemed desirable at this time.

The term "blackstrap" is given to the low-grade uncrystallizable residue of the sugar-making, or sugar-refining, process, which at one time, in Louisiana at least, was discarded as of no economic value, and, consequently, wasted, so far as its feeding importance was concerned.

The use of molasses as an appetizer and tonic for stock has been in vogue with owners and feeders for quite a length of time, however; but as a food nutrient of the carbohydrate class, its extensive and intelligent adoption dates back only to more recent years, and it is being utilized now, not only as a regular ingredient of mixed rations on plantations and farms, but by the commercial world in the various so-called "sweet feeds" that are to be found upon the market.

It should be understood, however, that while blackstrap is a most valuable food of its class, it is not a perfectly balanced food in itself, as it supplies, in the main, only one of the nutritive elements (carbohydrates) of a mixed and balanced ration.

It is valuable for at least four very good reasons, viz.: (1) Its palatability; (2) under normal conditions, its cheapness as a source of the carbohydrate element—sugar; (3) its high carbohydrate content—approximating 53 per cent; and (4) the almost complete digestibility of its contained carbohydrates.

It is the writer's opinion that the marked success which has attended its adoption during the past number of years is almost wholly due to its palatability; its condimental effect in promoting more perfect digestion of other feeds fed with it; and the readiness with which it can be absorbed into the blood system of the animal for purposes of nutrition.

The earlier analysis of blackstrap showed a somewhat higher percentage of carbohydrates—sugar; but owing to the increased efficiency in the process of producing sugar today, the per cent of its carbohydrates has been reduced to some extent.

The following may be taken as an average of its composition at the present time:

Dry Matter	Water	Ash	Carbohydrates
%	%	%	%
77.75	22.25	8.13	53.58

Some years ago the writer addressed a questionnaire to some forty-seven

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* Louisiana Planter, May 15, 1920.

[1] Director Louisiana Experiment Station.

large sugar plantation owners in Louisiana to try to obtain some more or less definite information regarding results they might have had after utilizing their blackstrap in the feeding of their work mules, the number of which approximated 4,500 head. In the replies received, practically everyone conceded to a considerable saving in the amount of his feed bills, ranging from ten to fifty per cent or more; and all seemed to refer to the marked diminution in the number of cases of dietetic troubles, such as colic, etc.; and that the health, and, therefore, the capacity of the animals for work, was very much improved.

One could scarcely wish for a higher endorsement of any food product, in the case of horses and mules at least.

The feeding of molasses is not now confined to horses and mules, however; it is being used with equal success in the feed-lot, in the dairy, in the hog-pen, etc.

From inquiries received, it would seem that some feeders, not hitherto accustomed to the use of molasses, do not appear to quite understand how it should be used to the best advantage.

Here it may be stated that its economic use would depend upon the availability and cost of other carbohydrate concentrates.

For example, if corn should be expensive, and molasses considerably cheaper, it would reduce the cost of the ration if part of the corn should be replaced by its equivalent weight of molasses, as the sugar in the latter, while not quite equal to in amount, approximates the starch in the corn, both of which have the same chemical composition. However, we do not deem it altogether advisable to make a complete substitution; but a partial substitution will frequently economize in the use of corn under high-priced conditions.

Again, it is better to feed molasses where the other ingredients of the ration are in a crushed or mealy condition so as to insure better mastication, or chewing, of the whole. When fed with whole grains alone, such as oats or corn, there is a tendency or liability on the part of the animals, especially horses or mules, to "bolt" their food without the necessary chewing of the grains.

For a well-balanced and economical ration for different classes of animals, we submit the following example:

For horses or mules weighing 1,000 lbs. doing hard work and per day:

2	lbs.	Cottonseed meal.
6	"	Cracked corn or chops.
6 or 7	"	Blackstrap.
12	"	Peavine, alfalfa, lespedeza, or any of the good leguminous hays.

[J. A. V.]

Report of the Committee of the American Chemical Society to Formulate Specifications for the Construction of a Polariscope for Laboratory Use.*

By W. D. Bigelow, *Chairman.*

Before the committee was appointed there had been considerable correspondence among sugar chemists regarding the desiderata for a polariscope for ordinary laboratory use. The correspondents included the sugar chemists of the United States, Hawaii and Cuba, and there were several conferences in the various places among the men who could arrange to meet. The correspondence regarding this matter was available to the committee and greatly facilitated our work. It has not been possible for our committee to arrange a meeting which all members could attend and most of our consultation has been by correspondence. There has been much personal conference among individual members of the committee, however, and one conference was arranged at which five members of the committee were present. We have also had the advantage of the cooperation of manufacturers of optical instruments in this country, one of whom has made a polariscope during the last year which complies with the requirements of the committee.

General Construction. The general construction of the saccharimeter outlined in these specifications should be as simple and substantial as possible. All parts of the instrument should be easily accessible and the number of bolts and screws for holding the parts in place should be reduced to the necessary minimum.

So far as possible the instrument should have smooth, plain surfaces and be without unnecessary ornamentation. An irregular ornamented surface affords grooves and crevices for the accumulation of dirt and is not easily cleaned.

The instrument should meet the requirements of exposure to a humid tropical climate and must be constructed to withstand corrosion.

The construction of the saccharimeter, so far as possible, should be of such a type that repair parts can be furnished separately, thus obviating the expense, the delay, and the danger of shipping the entire instrument. Wherever this is not practicable manufacturers should undertake to make repairs in a satisfactory manner without undue delay.

Height. The standard height of most saccharimeters from table to center of field eyepiece is between 32 and 34 cm. This height is convenient for manipulation with the elbow of the operator resting upon the table and has found most general approval.

Mounting. The saccharimeter should be mounted upon a rigid trestle support and not upon a tripod. Instruments mounted upon tripods are unstable and easily turned out of alignment, the result being an error in the zero point.

The base of the trestle should be a solid piece of metal at least 2 cm. thick,

* Journal of Industrial and Engineering Chemistry, May, 1920.

the bottom edge of which can rest at all points upon the table. A base elevated above the table by supporting knobs or projections lacks rigidity and has the disadvantage of permitting cover glasses and other objects to escape underneath.

As many chemists prefer to fasten their instruments to the table, the base of the trestle should be provided with slots or screw holes to facilitate this.

Lamp Supports. The lamp end of the trestle should be designed to accommodate a strong removable bracket for the convenience of those who may wish to use it as a lamp support, thereby keeping lamp and instrument always in undisturbed alignment.

The holder of the lamp must be placed at the proper focal distance and should be adjustable. Bracket and holder should be designed so as to prevent transmission of heat to the polarizer of the instrument.

For rooms of constant temperature the lamp should be in a separate room.

Trough. The trough, or tube holder, should be of solid metal, in one piece, and sufficiently thick to prevent denting or bending under ordinary conditions of usage. The diameter of the trough at the top should be about 3 cm. and should be adjusted exactly to fit the end pieces of the observation tubes. The cross-section of the trough should be semi-circular in shape. A wedge-shaped trough does not give the necessary support to inversion tubes or other tubes of unstable equilibrium.

The length of trough should be 42 cm. This length is necessary for the accommodation of the control tube which is used for verifying the accuracy of the scale. The short 20 cm. trough does not permit the use of the control tube and is also inadequate for the polarization of sweet waters and other dilute solutions.

The base of the trough should be supported to the frame of the trestle and there should be a 2 mm. space between its ends and the rest of the instrument. This clearance allows the escape of any liquid which may be spilled in the trough and protects against warping of the trough and transmission of heat to the optical parts when polarizations are made at high temperature. The base of the trough must be parallel with the optical axis of the instrument.

The trough should be made removable for the accommodation of other forms of tube supporters or baths that may be needed in special cases. Owing to the corrosive action of solutions, which may be spilled inside the trough, the screws for fastening the trough should be on the outside.

Trough Cover. The trough should be provided with a hinged cover for excluding light. The cover should be long enough to cover the 2 mm. space between the trough and splash-glass holders, and should fold back to a horizontal position where it can be used in case of need as a receptacle for tubes.

The hinges of the cover should not be riveted. Many chemists find the trough cover an encumbrance, and for the convenience of such it should be easily removable.

For the convenience of those who use continuous, or side-filled, polarization tubes, a slotted cover should be provided as an optional accessory.

Splash Glasses. The splash glasses at the ends of the trough, for protecting prisms and wedges against dust and drops of liquid, should be mounted in holders which can be quickly removed, cleaned, and replaced without the use of

tools. Slip holders with a tension spring are most generally preferred, and they should be designed to prevent sticking.

The two holders should be as near alike as possible, at least 1.5 cm. deep and so constructed that glasses can be easily removed for cleaning. For ease of replacement when damaged, the splash glasses should be of the same size as the standard polariscope tube cover-glass.

Quartz Wedges. For a commercial saccharimeter all chemists prefer the compensating single-wedge system. The wedge should be of sufficient length to give a range of scale from —35 to 115 sugar degrees.

If quartz of sufficient optical purity to give this lower range cannot be secured, a dextro quartz plate should be provided as an accessory for use in invert polarization.

The driving mechanism of the wedge should consist of a vertical rod supported to the front of the trestle frame and provided at the bottom with a milled head about 7 cm. from the table and convenient for operation with either hand.

The spiral rack and pinion with which the driving rod connects should operate smoothly and without lost motion.

Scale. The scale should be etched upon ground glass and read by transmitted light obtained from the light source of the instrument. The design of the instrument should be such that the scale can be illuminated, when continuous or control tubes are in upright position in the trough. The range of scale should be from —35 to 115. This upper limit is necessary for those who wish to determine purities without diluting below 20° Brix.

The scale should have an adjustable double vernier, for plus and minus degrees, and should easily be read to 0.05°, to which end the magnifying power of the reading microscope should be amply large The error of scale graduation should nowhere exceed 0.05°.

The adjusting screw for moving the vernier to the zero point of the scale should operate positively in either direction. In some instruments a spring is designed to act when the adjusting screw is withdrawn. The objection to such a spring is its liability to stick and not to operate as intended.

Before shipment, the scale of each instrument should be carefully standardized at suitable intervals throughout its entire range and the standardization values should be incorporated permanently in some way upon a plate attached to the instrument.

Protection Case. Scale and wedges should be enclosed in a tight protection case to prevent deposition of dust or spattering with drops of liquid. The covering of the case should be easy to take off, when it is desired to gain access to scale or wedge, by the removal of a few fairly large-size screws. The rim of the protection case should have a covered aperture for inserting the key of the adjusting screw.

Whenever desired the front of the case should be provided with a small thermometer having a range of 10° to 40° C. and with its bulb near the quartz wedge. The thermometer should be arranged so that it can be read in a darkened compartment by light obtained from the lamp which illuminates the instrument.

Screen. The protection case should be designed to accommodate a removable screen to protect the eye which is not in use from the glare of the lamp. The screen should have a diameter of about 15 cm. at the level of the two oculars.

Analyzer. While the analyzer is one of the parts which should require least attention, there are occasions when it needs to be adjusted. It should be made fairly accessible and be provided with simple means for firmly securing the adjustment.

Light Filter. The light filter should be placed between the polarizer and light source of the instrument and should be so supported that it can be quickly thrown into the field or out without disturbing the position of the instrument.

The standard bichromate cell should consist of a glass tube 3 cm. long encased in a metal jacket with threaded ends to accommodate the screw caps for holding the glasses. The cell should have a sufficient diameter so as not to require refilling because of air bubbles during an ordinary campaign (or more than twice a year).

Many chemists desire a lightly ground glass over the aperture at the lamp end of the instrument to equalize the light. Such a glass, if properly tinted, might serve the double purpose of light filter and equalizer. As a matter of convenience the instrument should be equipped with a light filter consisting of a glass plate of the same depth of color and absorptive power as the standard light filter.

Oculars. The oculars in front of the instrument for reading field and scale should focus with a screw motion. The sliding eyepiece is objectionable, owing to the ease with which it is pushed out of adjustment by the face of the observer.

The distance from center of field eyepiece to center of scale eyepiece varies in present instruments from about 3 to 6 cm. For convenience and rapidity in reading, the interval between the two eyepieces should lie within these limits.

Field. American chemists with few exceptions prefer the customary double field with vertical semi-circular halves. The field should be of good size, sharply defined, and not obscured with the rim or halo of extraneous light, which results from improper optical construction.

Polarizer. The preferences as to polarizer are divided between the Lippich and Jellet-Cornu prisms. Many chemists, while admitting certain advantages of the Lippich polarizer, complain of its frequent disintegration along the sharp edge of the half-prism upon which the telescope is focused, the result being an imperfect or shattered field. The disruption of the half-prism may result from a jar to the instrument or it may take place from no apparent cause. More saccharimeters are made unserviceable for this reason than for any other. The difficulty of repairing the damage, owing to the extreme fragility of the parts, renders the Lippich polarizer less suited for localities which are far distant from repair shops. Many chemists, on the other hand, who admit the greater stability of a modified Jellet-Cornu prism, complain of its lower degrees of sensitiveness owing to the pronounced dividing line of the field, the result either of too thick a film of balsam between the halves of the upper part of the prism or of imperfect alignment of the polarizer. The defects peculiar to each type of prism can largely be overcome by careful manufacture. There are many stable Lippich polarizers and many Jellet-Cornu prisms that are satisfactory in sensibility.

If manufacturers can make repairs rapidly and can furnish extra interchangeable half-prisms of easy adjustment, the usefulness of the Lippich polarizer would be much widened and the majority of chemists in fairly accessible localities would probably then prefer it. For remote tropical countries where repairs are difficult and time-consuming a modification of the Jellet-Cornu prism would probably be the better type. For these reasons the type of polarizer should in great measure be left optional with the purchaser. In their manufacture of polarizing prisms manufacturers should take every precaution to insure stability and to prevent drying out and cracking of the films of balsam cement.

A very serious complaint from tropical countries is the infection of the polarizer, analyzer, and other optical parts of the instrument by molds, the mycelia of which grow over the prisms, corroding their surface and obscuring the field. Efforts to prevent infection by enclosing the parts more adequately have not proved successful. The best means of preventing the growth of molds seems to be a construction that permits of easy accessibility and removal of parts for cleaning and for placing in desiccators during periods when the saccharimeter is not used.

Mounting of Prisms. Wax, as a mounting material for prisms, has proved objectionable in warm climates on account of its softening. A mounting in cork and plaster is said to be the most satisfactory.

Half-shadow Angle. The fixed half-shadow angle of the polarizer in most saccharimeters varies from 5 to 9 angular degrees, the choice of angle by different manufacturers seeming to depend somewhat upon the length and pitch of the quartz wedge. It is probable that for general commercial purposes the half-shadow angle should fall within this range. The sensibility is greater but the intensity at the end-point is less with the smaller half-shadow angle. Recent improvements in electric stereopticon lamps with concentrated filament and high candle power make it possible for manufacturers to adapt saccharimeters to a lower half-shadow angle than was formerly the case. For a normal weight of 26 grams the fixed half-shadow angle should have a magnitude of at least 7° for the average class of sugar factory raw products. The angle may be smaller than this for colorless products. The angle may also be reduced for raw products with instruments which are adapted to a normal weight of 20 or 16.29 grams.

Chemists who work constantly with dark-colored syrups and molasses prefer a polarizer with a rather wide half-shadow angle. It would, therefore be a distinct advantage if manufacturers could supply interchangeable polarizing prisms —one with a medium half-shadow angle between 5 and 8 angular degrees and another with a higher half-shadow angle between 9 and 12 degrees.

Polarizing prisms should be mounted in metal holders which can be easily removed and inserted and the adjustment of which can be quickly and securely fixed.

The sleeve, or cover, which protects the polarizer should be easy to take off by the removal of a few fairly large-sized screws.

The standard temperature for the calibration of saccharimeters shall be 20° C. For laboratories working at a temperature materially different from

this, correction of polarizations to 20° C. may be made at discretion by any of the following methods:

1—By the use of a table of temperature corrections for each particular product.

2—By changing the normal weight.

3—By changing the capacity of the flask.

4—By changing length of normal tubes.

5—By having a scale calibrated by the manufacturer so that it is correct for the temperature desired.

With the exception of the first method these methods of correction are strictly applicable only to products which contain no other optically active constituent than sucrose. For general sugar house and food products containing several sugars, in case constant temperature polarization at 20° C. is not permissible, Method 1 gives results which are nearest to those obtained at the standard temperature.

Standard or Normal Weight.

A large majority of chemists believe that the present is a most suitable time to abandon the inaccuracies and inconveniences of previous national standards and to agree upon a saccharimetric scale which shall be accurate, convenient, and so far as possible international. From opinions expressed by leading chemists in America, England and France, it is apparently more easy to secure general agreement, in these three countries at least, upon the so-called international normal weight of 20 grams proposed in 1896 by Sidersky and Pellet. According to this standard the 100 degree point of the saccharimeter scale shall indicate the polarization of 20 grams chemically pure dry sucrose dissolved in distilled water to 100 metric cc. and polarized in a 20 cm. tube, the temperature of solution and instrument to be 20° C. and the illumination to be white light filtered through a solution of potassium bichromate of such concentration that the percentage content of the solution multiplied by the length of the layer of solution in centimeters is equal to nine.

While many chemists believe that all saccharimeters hereafter manufactured for American use should be graduated solely according to this proposed international standard, it is the opinion of this committee that pending international agreement upon the question manufacturers of saccharimeters should standardize their instruments according to the scale desired by the individual purchaser.

In the adoption of an international saccharimeter standard this committee believes that—in order to avoid the numerous unfortunate changes which in the past have characterized previous standards, and in order to have absolute accuracy and uniformity in different parts of the world—the percentage content, specific gravity, refractive index and angular rotation of the normal sugar solution, and the angular rotation, in terms of sodium and mercury monochromatic light, of the quartz plate, which shall read 100 upon the saccharimeter scale, should be established by carefully conducted experiments in the governmental laboratories of the different countries; and that from the results thus found international agreement shall be reached in regard to the final values, upon which

manufacturers shall base the standardization of their instruments. The U. S. Bureau of Standards has already completed investigations upon the rotation values and other constants of the 26 and 20 gram normal sugar solutions.

It is not intended that the establishment of an international normal weight shall throw out of use the large number of saccharimeters which are at present doing excellent service. The transition is to take place gradually as in the change from Mohr to metric cc. Old instruments as they wear out are to be replaced by instruments with the new scale. Owners can also have their old instruments rescaled, but this should be done only when the accommodation of scale, polarizer, lenses, etc., secures an equal or greater accuracy in reading. If an old instrument is not rescaled it should at least be standardized and the weight of pure sucrose necessary to read 100 upon its scale be engraved or stamped upon a plate attached to the instrument. Correction of instruments by the adjustment of an incorrect scale to a correctly standardized quartz plate is open to criticism, as a scale thus adjusted is accurate only for the reading of the plate and a considerable error may be introduced at other points of the scale, especially when readings have to be corrected for dilution. [R. S. N.]

Effect of Varying the Amount of Inoculum and Concentration on the Deterioration of Sugar by Molds.*

By Nicholas Kopeloff.[1]

In a previous paper[2] it was shown that a decrease in concentration of films of known concentration in laboratory-made sugars was responsible for an increase in deterioration when heavily inoculated with mold spores. The industrial application of this conclusion is determined by two important variable factors, namely, the concentration of the films surrounding the sugar crystals, and the degree of infection. Therefore, a further investigation of the influence of these factors was considered necessary.

The method of procedure was identical with that outlined in the previous article, except that the incubation period was 5.5 mo. instead of one month. A series of sugars with films of known composition was made in the laboratory by coating large crystals of sterilized sugar with sterilized blackstrap molasses and 60° Brix sugar syrup in definite proportions and purging in the centrifugal, a method previously employed with success. Blackstrap molasses, 5/6 blackstrap + 1/6 syrup, 4/6 blackstrap + 2/6 syrup, and 3/6 blackstrap + 3/6 syrup when arranged in order of increasing moisture ratio are designated as Concentrations A, B, C, and D, respectively. These sugars were inoculated with *Aspergillus*

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1 Department of Bacteriology, Louisiana Sugar Experiment Station, New Orleans, La.

2 Journal of Industrial and Engineering Chemistry, 12 (1920), 256.

niger, Aspergillus Sydowi Bainier and *Penicillium expansum,* at the rate of 100, 1000 and 10,000 spores per gram. At the end of 5.5 mos. incubation at room temperature the contents of each flask were analyzed for sucrose by direct polarization and modified Clerget, and for reducing sugars and moisture. It has already been shown[3] that the most satisfactory criterion of deterioration of sugar is the gain in per cent of reducing sugars. In order to summarize the results as briefly as possible, there is given in Table I the increase over check of the averages of closely agreeing triplicate determinations of reducing sugars. The abbreviation M. R. stands for moisture ratio, which value is derived as follows:

$\text{M. R.} = \dfrac{\text{Moisture}}{100 - \text{Polarization}}$; *Asp. n.* is the abbreviation for *Aspergillus niger,* while *Asp.* S. B. and *Pen.* represent *Aspergillus* Sydowi Bainier, and *Penicillium expansum.*

TABLE I—SUMMARY SHOWING THE INFLUENCE OF AMOUNT OF MOLD INOCULUM ON THE DETERIORATION OF SUGARS WITH FILMS OF KNOWN CONCENTRATION. INCREASE IN PER CENT REDUCING SUGARS OVER CHECK.

No. Spores per Gram.	Concentration. A M. R. = 0.14.			B M. R. = 0.16.			C M. R. = 0.18.			D M. R. = 0.24.		
	Asp. n.	*Asp.* S. B.	*Pen.*	*Asp. n.*	*Asp.* S. B.	*Pen.*	*Asp. n.*	*Asp.* S. B.	*Pen.*	*Asp. n.*	*Asp.* S. B.	*Pen.*
100	...	...	...	...	0.09	0.01	...	0.09	0.07	...	0.10	0.10
1000	...	0.02	0.02	...	0.05	0.04	0.12	0.22	0.17	0.04	0.18	0.18
10,000	0.04	0.21	0.11	0.03	0.12	0.11	0.27	0.31	0.28	0.12	0.27	0.28

It will be seen from this table that in every instance but one an increase in the number of spores per gram caused an increase in per cent of reducing sugars over check. This held true not only at every concentration employed, varying in moisture ratio from 0.14 to 0.24, but likewise for every organism used at any single concentration. This fact is very significant and indicates conclusively that an increase in degree of inoculation of mold spores at any definite concentration is responsible for an increase in deterioration of sugar. This corroborates our previous work where solutions varying from 10 to 70 per cent were employed,[4] as well as the results obtained in the experiment just concluded,[5] where an inoculation of 100,000 spores per gram at each of the above-mentioned concentrations was employed. A closer scrutiny of the results presented in Table I reveals the fact that the increase over check of reducing sugars with an inocu-

[3] Louisiana Bulletin 166.
[4] J. Agr. Res. 18 (1920), 537.
[5] Journal of Industrial and Engineering Chemistry, Loc. cit.

lation of 100 spores per gram is insignificant at practically all concentrations. The same is true of an inoculation of 1000 spores in the two higher concentrations, namely, A and B. This is of practical importance in defining the limits at which deterioration occurs, since in plantation granulated sugars the moisture ratio may be said ordinarily to be below 0.18. It is generally considered that good Cuban raw sugar likewise should have its moisture ratio below 0.25 to 0.33. Thus, it might be inferred from the foregoing data that where the moisture ratio is below 0.18, mold infection of less than about 5,000 spores per gram would cause slight, if any, deterioration. As a rule we have rarely found sugars which had more than 250 mold spores per gram, although no quantitative survey has been carried out as exhaustively as might have been desirable.

When the two lower concentrations C and D are considered, we find that there is evidence of deteriorative activity with 100 spores per gram, while with more than 1000 spores the deterioration is quite appreciable. It would appear, therefore, that for safety (from the standpoint of mold infection) a sugar having a moisture ratio of 0.17 to 0.18 would have to contain less than 100 mold spores per gram. On the other hand, a mold infection of more than 10,000 spores per gram will cause a deterioration in sugars with moisture ratios varying from 0.14 to 0.24. It may be noted in this connection that in the previous investigation an inoculation of 100,000 spores per gram was responsible in one month for a deterioration in sugars with moisture ratios varying from 0.08 to 0.20.

An interesting fact which corroborates all our previous work with sugars, as well as solutions, is that at any definite concentration and with an equal number of spores per gram *Aspergillus* Sydowi Bainier is more effective than *Penicillium expansum,* which in turn is more effective than *Aspergillus niger* in deteriorative activity.

TABLE II—SUMMARY SHOWING THE INFLUENCE OF CONCENTRATION OF FILM ON DETERIORATION OF SUGARS BY MOLDS

Concentration	Moisture Ratio	Per Cent Gain in Reducing Sugars Over Check								
		100 Spores per G.			1000 Spores per G.			10,000 Spores per G.		
		Asp. n.	*Asp. S. B.*	*Pen.*	*Asp. n.*	*Asp. S. B.*	*Pen.*	*Asp. n.*	*Asp. S. B.*	*Pen.*
A	0.14	...	...	...	...	0.02	0.02	0.04	0.21	0.11
B	0.16	...	0.09	0.01	...	0.05	0.04	0.03	0.12	0.11
C	0.18	...	0.09	0.07	0.12	0.22	0.17	0.27	0.31	0.28
D	0.24	...	0.10	0.10	0.04	0.18	0.18	0.12	0.27	0.28

In Table II is presented a summary of results so arranged as to show the influence of concentration of film on the deterioration of sugars by molds It must be stated at the outset, however, that where the increasing increments of moisture are so slight as in the present instance, and especially when dealing

with the activity of microorganisms over such a long incubation period, it is hardly to be expected that the differences will be very sharply defined. However, it will be observed that as a rule an increase in moisture ratio (which actually signifies a decrease in concentration) is responsible for an increase in deterioration with any single inoculation. It is not necessary to repeat here what was stated in the discussion of Table I concerning the limiting effects of concentration with any definite inoculum. Suffice it to say that this work fits in very closely with our preceding investigations and proves quite conclusively that with a high mold infection, deterioration takes place in sugars with moisture ratios below 0.14, or, according to the previous experiment, at 0.08. This substantiates the claim previously made that "the factor of safety for sugars well infected with fungi would appear to be lower than is generally supposed," and defines more clearly what such limits must be. In other words, knowing the number of molds present in any sugar, it may be predicted (from the standpoint of mold infection alone) what deterioration may be expected in a storage period of about 5 months with a sugar of known moisture ratio. It is to be assumed that at the present time we have carried through to completion, from a survey of mold speciess in sugar sugars are not stored for such a long period of time, but the differences obtained upon a long incubation period are not so much greater as to invalidate the above generalizations, as will be seen from Table III, which gives a comparison in the reducing sugar content of inoculated sugars with films of Concentration D (moisture ratio = 0.24) after 1 and 5.5 months, respectively. It will be readily seen that the differences in incubation as represented by the gain in per cent of reducing sugars are indeed slight when compared with the initial gain over check in one month.

TABLE III—COMPARISON IN CONTENT OF REDUCING SUGARS OF INOCULATED SUGARS (WITH FILMS OF CONCENTRATION D) AFTER 1 AND 5.5 MONS. INCUBATION, RESPECTIVELY.

Incubation	Check	*Asp. n.*	Gain over Check	*Asp.* S. B.	Gain over Check	*Pen.*	Gain over Check
After 1 month	0.23	0.44	0.21	1.10	0.87	0.77	0.54
After 5.5 months	0.23	0.53	0.30	1.46	1.23	0.87	0.64
Gain in reducing sugars, per cent......	0.00	0.09	...	0.36	...	0.10	...

Next to the elimination of deterioration, the most important commercial consideration is prediction of the keeping quality of a sugar. Table IV is a tentative plan based on the results obtained in all our investigations which will give some conception of the deterioration to be expected from a definite number of molds in sugars of known moisture ratio. It must be clearly understood that this plan is advanced with considerable diffidence, and that its value rests on further verification. Furthermore, it is of importance to note that in the above table mold infection only has been considered. We have data which are concerned with deterioration due to bacterial infection and unquestionably the bac-

terial flora would seriously influence the deterioration of sugars as shown in the important researches of previous investigators. However, since individual molds, such as *Aspergillus* Sydowi Bainier, *Penicillium expansum,* and *Aspergillus niger,* are vastly more efficient in their deteriorative activity than any bacteria that have come to our attention, and since the first-named mold is to be found in practically all sugars, it may be that the above table will prove of some value to those who are ready to take cognizance of the molds which are undoubtedly causing large economic losses in the sugar industry. In Table IV it will be seen that the facts previously discussed have been so arranged that one may tell at a glance what deterioration, if any, might be expected. It was not deemed necessary to carry out the work in moisture ratios beyond 0.24, because it is generally conceded that sugars having a moisture ratio above 0.30 are susceptible to deterioration. Browne,[6] Owen,[7] and others have advanced much valuable evidence on this point.

TABLE IV—DETERIORATION TO BE EXPECTED FROM A DEFINITE NUMBER OF MOLDS IN SUGARS OF KNOWN MOISTURE RATIO.

$$\text{Moisture Ratio} = \frac{\text{Moisture}}{100 - \text{Polarization}}$$

Number of mold spores per g.	0.08	0.14	0.16	0.18	0.20	0.24	Over 0.24
0–100	—	—	±	+	+	+	+
100–1,000	—	±	±	+	+	+	+
1,000–10,000	±	+	+	+	+	+	+
10,000–100,000	+	+	+	+	+	+	+

\+ Deterioration.

— No deterioration.

± Slight, if any, deterioration.

This paper may be said to round out one phase of the problem of sugar deterioration, namely, that concerned with the importance of mold infection, which we have carried through to completion, from a survey of mold spores in sugar and their deteriorative activities in sugars and solutions to a study of the effect of varying the amount of inoculum and concentration on deterioration.

The writer wishes to thank Messrs. D. F. Stanfill, Jr., and R. S. Hays for their help with the chemical analyses and the Station staff for their assistance, and is indebted to Mr. W. L. Owen for his kindness in reading the manuscript.

Summary.

1—An increase in number of mold spores inoculated into sugars (with films of varying concentration) is responsible for an increase in deterioration.

2—A decrease in concentration of the films surrounding the sugar crystals is responsible for an increase in deterioration.

3—A table is presented showing the deterioration which may be expected from a definite number of molds in sugars of known moisture ratio.

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6 Journal of Industrial and Engineering Chemistry, 10 (1918), 178.

7 Louisiana Bulletin 162.

4—At moisture ratios of less than 0.18 there is little, if any, deterioration with a mold infection of less than 5,000 spores per gram. More than this number of spores induces deterioration. At moisture ratios above 0.18, deterioration occurs with upwards of 100 spores per gram.

5—At any definite concentration and with an equal number of spores per gram *Aspergillus* Sydowi Bainier is more effective than *Penicillium expansum* or *Aspergillus niger* in its deteriorative activity. [W. R. M.]

On the Burning of Fuel Oil.*

By H. J. Vandereb.

The shortage of coal and abnormal rise in coal prices of the last few years has given rise to a lively interest in the use of fuel oil under power boilers. Quite naturally, comparison as regards cost of coal and oil is the principal factor in this. For certain localities such a comparison is at present favorable to the use of oil. Especially is this true for New England and other points on the Atlantic Coast, remote from the coal fields. Add to this the uncertain delivery of coal of the present time from causes we need not here mention, and you have a fair index to the oil fuel situation.

As to how long these price relations can possibly continue, it is practically impossible to make a reasonably safe guess. From the present knowledge of the available world supplies of oil and coal, which necessarily is rather vague, it seems, however, to be generally taken as a foregone conclusion that the oil supply will have ceased many centuries before coal will show signs of exhaustion. Undoubtedly at some future day, which may be in the lifetime of the present generation, the operation of the inexorable law of supply and demand may give back to coal the nearly undisputed monopoly it so long has enjoyed in the field of steam power generation. So long as the price remains favorable, however, oil will be a big factor in power plant operation and the present indications are that this may be for a number of years to come.

It is the purpose of this article to give a few helpful hints, gathered from the best information available, to steam users who desire to look into the desirability of changing from coal to oil for their boiler plants. In every case it is desirable that a reliable estimate be made in advance, of all the cost involved in making the necessary changes in the equipment. While the cost of the actual oil burning apparatus is light as compared with, for instance, mechanical stokers, there may be costly changes necessary in the boiler settings in order to obtain a reasonably high efficiency, which may drive the cost up to a disappointing figure. In addition to this, account should be taken of the possible necessity of installing

*Reprint from "The Locomotive" of the Hartford Steam Boiler Inspection and Insurance Company, January, 1920.

extensive storage tank capacity, depending on the proximity of the plant under consideration to an oil distributing center. For plants that are a considerable distance away from such an oil depot it is suggested to have a storage capacity of from thirty to forty days' supply to take care of any interruptions of the regular delivery of the oil. Steam plants that have the good fortune of being located right near an oil depot can of course avoid a heavy investment in storage tanks, and for such plants a week's supply on hand might be considered sufficient. But even for such installations, especially if they be public service plants with contracts for their power output, business foresight may suggest the desirability of the right proportion of reserve supply to insure continuous service under unusual circumstances. With a further view to the possible serious interruption of the oil supply at the source it has been suggested that no oil burning installation should be undertaken that would not permit changing back to the use of coal in a reasonably short time. In making estimates on proposed oil installations and comparing the cost of the oil itself with that of coal, use can be made of a handy approximate rule, sufficiently accurate for practical purposes, which is the simple relationship between the cost of the two fuels as pointed out by Mr. W. M. McFarland. This is, that for equal steam production the fuel cost will be the same when the number of dollars of the price of coal per ton (of 2,240 lbs.) is double the number of cents of the price of oil per United States gallon. This rule is based on the respective average heat values of oil and coal per lbs. and takes into account the better efficiency obtainable with oil than is possible with coal. Any other possible economies incident to the use of oil, such as the lower labor cost of handling fuel oil as compared with that of coal and ashes, are not included in this rule.

The fuel oil that is at present sold for power purposes is, with very little exception, the heavy residuum that remains after taking off by partial distillation from the crude oil the valuable lighter hydro-carbons, naphtha, gasoline and kerosene. This so-called "topping" of the crude oil enhances the value of it as fuel rather than diminishing it, as the flashpoint is thereby raised to a point where the fuel can be handled with greater safety, especially after being heated to the temperature necessary for properly atomizing it at the burners. The calorific value of the "topped" oil is not any less than that of the crude oil, in fact it is even a little higher.

The Advantages of Oil Over Coal.

From a number of viewpoints oil is an attractive fuel for steam generation. As already indicated in the foregoing it is possible to obtain a higher efficiency with oil than with coal. It is comparatively easier, so far as physical effort is concerned at least, to obtain almost perfect combustion with oil burning and keep out of the furnace unnecessary excess air from the fact that there are no furnace doors opened every few minutes as with the hand firing of coal and there is no cleaning of fires with its attendant serious cooling off of the furnace. The required intensity of the heat from the burners is under practically instantaneous control to meet changes in the load. There is furthermore possible a con-

siderable saving of labor in an oil burning plant as compared with that required for the handling of coal and ashes and there is a complete absence of dust.

For the small plant of one or two boilers a saving in the labor item should not be expected, since of course for such an installation the same number of men will be required to tend to the burners as would be to shovel coal in the furnace. There are, however, many small plants where it could be expected of one man, with more justification from a safety standpoint, to tend to both the engine and boiler, if oil were used, than where he has considerable coal shoveling to do. But for the larger plant the labor economy is a real factor. One man can tend a considerable number of oil fired boilers with almost the same facility as he can one boiler. One other feature that may be mentioned in favor of oil fuel as compared with coal, is that the troubles of spontaneous combustion, so common with coal of high sulphur content, are entirely excluded with oil fuel.

There are almost no real disadvantages connected with oil burning to offset the several advantages mentioned. The one serious obstacle that can be mentioned is that in congested city districts the use of oil may be made prohibitive by local ordinances requiring special conditions with regard to location and isolation of storage tanks with a view to safety in case of fire. Some of this trouble, however, may be overcome by piping the oil underground to the plant from a point where oil can be conveniently stored with better safety.

The oil as received may contain a certain percentage of moisture, which must be eliminated by giving it time to settle to the bottom of the storage tanks. It is therefore desirable to have always more than one tank for any conditions of required storage capacity so that the oil as it is used may always be pumped from a tank in which the settling of the moisture is as complete as practicable. Each tank should be provided with a bottom drain cock at its lowest point to run off any collected water or dirty oil.

At the ordinary outdoor temperatures, especially in the northern latitudes, it is necessary to heat the oil in the storage tanks to reduce its viscosity to a point where it can be pumped. As it is too wasteful to attempt to heat the whole tank to the desired temperature it is entirely possible to accomplish this by placing a steam coil right near the point where the suction pipe enters the tank. On all piping used for the transmission of oil it is desirable to have a steam connection so that they may be blown through and cleared of any accumulations of silt which is more or less present in all fuel oil. It is absolutely essential to have some effective form of strainer placed in the suction pipe leading to the pump in order to catch the fine grit and so to prevent undue wear of the pump cylinders. In order to eliminate the pulsations of the pump, so that a steady flow may be had at the burners, the pumps should be provided with an ample air chamber.

Heating of the oil is furthermore a necessity to aid in the proper atomization at the burner. It is most convenient and economical with the heavy oils now being used to do the heating of the oil in two steps, namely, to raise the temperature of the oil near the suction outlet of the storage tank sufficiently to reduce its viscosity to a point where it can be pumped and to have in the fire-

room a separate heater in which the oil can be given the desired temperature for proper atomization. The final temperature of the oil just before atomization is usually about 140° to 160° Fahrenheit, where the oil is atomized by means of steam, but it is best to find by trial the most suitable temperature for each particular oil used to effect the best economy. Great care should be exercised to not heat the oil above its flashpoint. The flashpoint of an oil is the temperature at which inflammable vapor begins to be liberated at its surface. Thermometers should be present on the suction pipe leading from the storage tank to the pump and on the pressure pipe between the pump and the burners so that at all times proper control of the temperature may be had. The inflammable vapors referred to are a distinct danger and may give rise to disastrous explosions in the combustion space of the boilers, when, for instance, the oil valve to a burner is inadvertently left partly open under an idle boiler. Such gas explosions are known to have done great damage to the setting walls and serious personal injury. Aside from this danger the proper operation of the burners is affected by the presence of vapor in the pipes as the oil will under such conditions flow irregularly, causing sputtering of the flame.

Some Details of the Burners.

The function of an oil burner is to scatter the oil in a spray of minute particles to make it possible for the oxygen of the air to come in contact with as much surface of the fuel as it is feasible to expose it. A solid stream of oil has a small surface as compared with the aggregate surface of all the minute oil drops that result when the solid stream is broken up into a fine spray. The work performed by the atomizing agent is simply the work of stretching the surface of the oil, hence the finer the spray the better are the chances for perfect combustion. The only limitation on the fineness of spray is the cost involved in producing it.

The burners that are most commonly used can be classified under two general types: 1st, spray burners, in which the oil is atomized by means of a jet of steam or air, and, 2d, mechanical burners, in which the oil is forced under considerable pressure through a small aperture of particular shape causing it to break up into small particles. As the small aperture of the mechanical burner will wear quickly larger by any grit in the oil, thus rendering it useless, the thorough straining of the oil is especially important when mechanical burners are used. It is, however, well for any type of burners to have a strainer in the pipe between the pump and the burners to catch any gritty or solid substance that may pass the strainer in the pump-suction line.

Mechanical burners have an advantage over those that atomize the oil by means of an air jet because of the necessity of an air compressor with the latter type. They also have, theoretically at least, an advantage over steam spray burners because of the fact that all steam that is introduced into a furnace leaves the furnace (when combustion is complete) as steam, which carries with it some of the heat generated from the fuel, entailing a certain amount of loss. It is sometimes asserted that the burning of the hydrogen that is set free when the steam is decomposed by the high furnace temperature into hydrogen and

oxygen, will add a certain amount of heating value to that of the fuel. The fallacy of this will be obvious when one considers that it takes just as much heat to decompose the steam into its component elements, hydrogen and oxygen, as can possibly be realized when these elements are again united by combustion.

Another advantage of mechanical burners over steam spray burners is that they are generally better adapted to take care of wider variations of load, which necessarily is conducive to better economy under certain conditions of operation. However, the extreme simplicity of the steam atomizing burner and the excellent economy obtained with it when constructed on correct principles, together with the comparatively low oil pressure and temperature it requires, has made this type the favorite for stationary work. Burners using air as an atomizing agent are in successful operation, but steam atomizing burners are used more generally. Wherever the loss of fresh water is not a vital factor the latter are usually the most satisfactory. The steam consumption has been found for the better make of burners to be approximately 2% of the total steam generated.

From a safety standpoint a so-called flat-flame burner is preferable over a burner producing a cone shaped flame for most types of boilers, as it is simpler with the former to avoid the impinging of the flame on portions of the heating surfaces of the boiler. Localization of the intense heat of the flame on tubes or shell of a boiler will invariably result in overheating and blistering of the metal and should be carefully guarded against. Space forbids a detailed description here of the different types of burners on the market. Such of our readers as are interested in further perusal of this detail are referred to "The Science of Burning Fuel Oil," by W. N. Best, and "Oil Fuel," by E. H. Peabody.

Ample Combustion Space an Absolute Requirement.

The selection of the right type of burner, while of course important, is of less significance in obtaining the proper boiler efficiency than is the proper furnace volume and general design of the furnace. The ideal conditions of an oil furnace are that the particles of burning oil have an opportunity to linger just long enough in the furnace to be completely consumed before coming in touch with the relatively cool boiler surfaces, which would extinguish them, with the possibility that they are re-ignited higher up in the setting or in the uptake with a resultant waste of heat.

Ample space must therefore be provided in the primary combustion chamber; more indeed than for almost any other fuel. This extremely important fact may make the change from the use of coal to oil prohibitive for boilers that are set low.

It has proved feasible with existing coal burning boilers, in which the distance above the grate is not less than about 40 inches, to form a chamber for the oil flames by placing a layer of firebrick over the gratebars, leaving a sufficient number of openings in this layer of brick for air admission. It is safe to say, however, that it is best in any case, both from a safety and an economy standpoint, to remove the gratebars and install a flat checkerwork of firebrick to take the place of the grate, but placed close to the ashpit floor, leaving only sufficient space under the checkerwork to form an air duct.

The bridgewall should then be cut down to about the top of this checker-work. In view of the high temperature to which the brickwork in an oil furnace is subject, which may reach 2800° to over 3000° Fahrenheit, only the best quality of firebrick should be used. It is impossible to give any sort of a definite rule for the proper amount of required combustion space. This can best be determined for each individual installation and its surrounding conditions by some-one having extended experience with oil burning.

For water tube boilers of the inclined tube type the so-called "rearshot" burner should be used. This name applies to location of the burner rather than to type. It simply means that the burner is placed just in front of the bridge-wall and shoots the flame toward the front of the boiler. The objects gained by this are that the flame projects in the direction in which the furnace increases in volume, due to the fact that the tubes are inclined toward the front, and the possibility of the flames impinging on the tube surfaces is practically excluded.

Fuel oil is successfully being used under vertical firetube boilers of the Manning type, but it is found that there is a tendency that not all the tubes participate in transmitting the products of combustion. The tubes directly over the burner proper are apparently idle, while the tubes in the rear or the direction of the flame transmit all the heat. In such a case, good use may be made of retarders, consisting of spirally twisted strips of sheet metal, placed in the rear tubes which will have the effect of distributing the hot gases more uniformly.

Fuel Economy Hinges Largely on Damper Adjustment.

The proper amount of draft through an oil burning furnace is a matter of great importance and on it hinges largely the success or failure of the installation in competition with coal. Less draft is required for successful burning of oil than in the case of a coal furnace of the same relative capacity. The reasons for this are that with oil burning the draft does not have to overcome the same retarding influence as is produced by a fuel bed, and the action of the oil burner itself is moreover to some extent that of a forced draft. The volume of gases for a given rating is smaller with oil burning than with coal. From this it follows that it is not necessary to have as large a stack area for oil burning boilers, nor does the stack have to be as high as for coal burning of the same capacity. The proper amount of draft to be allowed when changing over an installation from coal to oil burning can be taken care of by keeping the stack damper partly closed, but it is better, and it makes the installation more fool-proof, to contract the area of the gas passage of a stack of too large capacity by means of a fixed plate with an opening in the center of the required size.

On the other hand there must be a sufficient draft suction to steadily carry off the products of combustion at a certain maximum rate which can only be determined by test for the best obtainable economy of fuel. If an insufficient amount of draft is allowed at the stack so that the action of the burner as a draft producer is relied on to push the gases, the action of the heat on the brick-work of setting walls and baffles will cause them to rapidly deteriorate. It is, therefore, a case of striking a happy medium between the evil of too much draft causing waste of fuel and that of not enough draft involving high upkeep cost.

As stated before the question of allowing just the right amount of draft is very important for proper economy and because of the fact that resistance to the draft is considerably less through an oil burning boiler than through a coal fired boiler, the handling of the damper is a much more sensitive operation with oil than it is with coal. It is, therefore, almost needless to state that a suitable draft gauge, located so that it can be conveniently read, is practically indispensable when economy is desired. Carelessness in manipulating the draft will invariably lead to gross waste of fuel.

In one installation, that recently came to our notice, the records of oil consumption showed a "mysterious" gradual increase, until finally it was nearly double what it had been at first, although the steam output from the boilers was practically unchanged. The reason for this marked increase in the oil consumption was not far to seek. The emphatic and careful instructions, given at the time the oil equipment was installed, had "wore off" and the firemen had come to regard the close regulation of the draft as a useless bother. Consequently they were running with the stack damper and ashpit doors wide open, causing a short white flame, which they no doubt regarded as hotter and therefore more efficient. The result was, as stated, a doubling up of the oil consumption. Here was a case where, with practically no effort, about ten barrels of oil per day could have been saved over a considerable period.

A clear stack on an oil burning installation is usually an indication that too much draft is passing through the furnace with a resultant low efficiency, since all the unnecessary excess of air simply acts as a cooling agent and carries heat up the stack that ought to have served in making steam.

A slight haze coming from the stack indicates that conditions are more nearly ideal. In order to establish the best furnace conditions for any given load, the most satisfactory method is, of course, by means of flue gas analysis, but in the absence of the proper apparatus for this, use can be made of a reasonably reliable and simple rule. When the furnace is well alight and the walls uniformly heated up to a high temperature, the draft should be pinched down by gradually closing the stack damper to a point where the flames have a slightly smoky fringe, when the damper should be opened again just sufficiently to clear the flames. [W. E. S.]